The Stars Above Us

ERNST ZINNER

ALLEN AND UNWIN

THE STARS ABOVE US

1. *Aztec sacrificial stone with representation of the sun, the four proto-suns, cardinal points and the twenty days of the month*

The Stars Above Us

* OR THE *

CONQUEST OF SUPERSTITION

PROFESSOR

ERNST ZINNER

Director of the Remeis Observatory
Bamberg, Germany

*

TRANSLATED BY W. H. JOHNSTON

LONDON

GEORGE ALLEN & UNWIN LTD

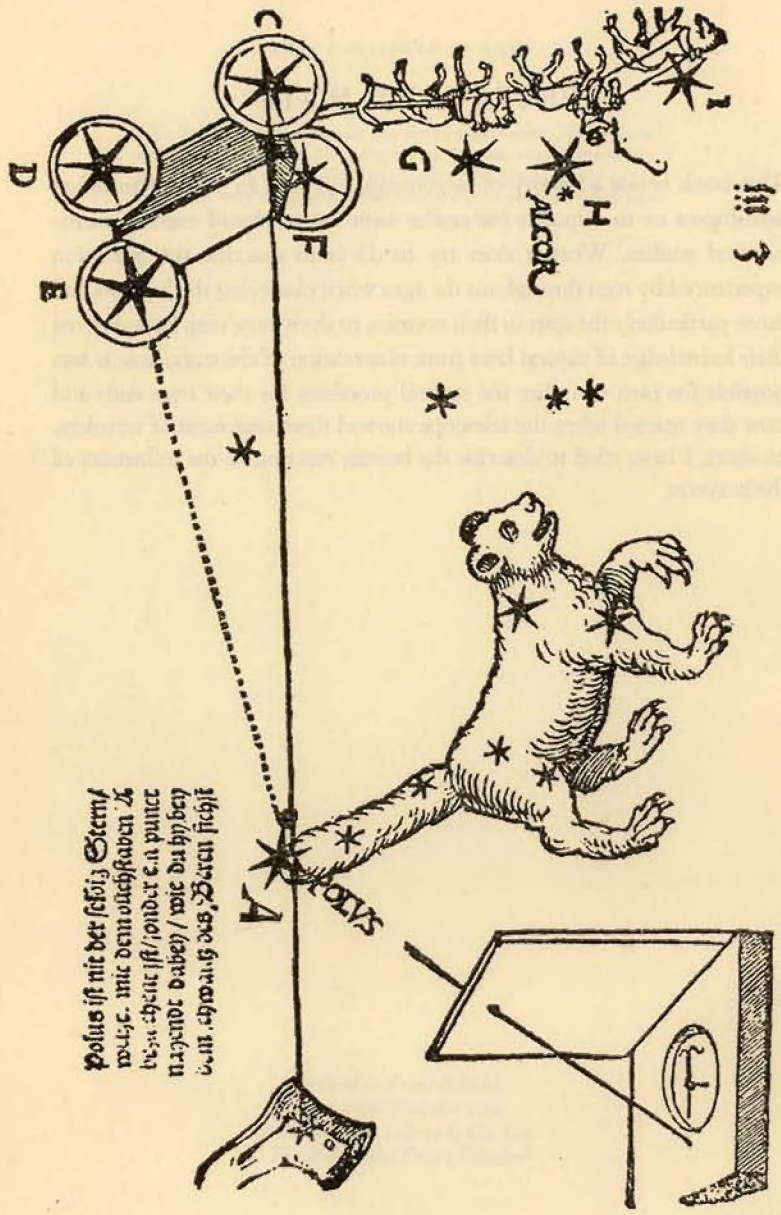
Ruskin House Museum Street

FIRST PUBLISHED IN 1957

Printed in Great Britain
in 12 *point Fournier type*
by Robert MacLehose & Co. Ltd.
The University Press, Glasgow

PREFATORY NOTE

This book is not a history of astronomy, nor is it an attempt to refute astrologers or to acquaint the reader with the results of modern astronomical studies. What it does try to do is to describe the attraction experienced by men throughout the ages when observing the heavens and more particularly the stars in their courses, to show how men have derived their knowledge of natural laws from observation of the stars, how it was possible for men to utilise the natural processes for their own ends and how they reacted when the telescope showed them undreamt of wonders. In short, I have tried to describe the human reaction to the influences of the heavens.



1. The Little Bear and Great Bear represented as a cart and miniature rider

CONTENTS

PLATES

FIGURES

Details of the references appear in the Bibliography

INTRODUCTION

In his *Revolt in the Desert* T. E. Lawrence records the conversation he had one night in 1917 with certain Arab Bedouins.

'Nasir rolled over on his back, with my glasses, and began to study the stars, counting aloud first one group and then another; crying out with surprise at discovering little lights not noticed by his unaided eye. Auda set us on to talk of telescopes—of the great ones—and of how man in three hundred years had so far advanced from his first essay that now he built glasses as long as a tent, through which he counted thousands of unknown stars. "And the stars—what are they?" We slipped into talk of suns beyond suns, sizes and distances beyond wit. "What will now happen with this knowledge?" asked Mohammed. "We shall set to, and many learned and some clever men together will make glasses as more powerful than ours, as ours than Galileo's; and yet more thousands of astronomers will distinguish and reckon yet more thousands of now unseen stars, mapping them, and giving each one its name. When we see them all, there will be no night in heaven."

' "Why are the Westerners always wanting all?" provokingly said Auda. "Beyond our few stars we can see God, who is not behind your millions." "We want the world's end, Auda." "But that is God's," complained Zaal, half angry. Mohammed would not have his subject turned. "Are there men on these greater worlds?" he asked. "God knows." "And has each the Prophet and heaven and hell?" Auda broke in on him. "Lads, we know our districts, our camels, our women. The excess and the glory are to God. If the end of wisdom is to add star to star, our foolishness is pleasing." '[1]

What was the force making men dissatisfied with their ideas about sun, moon and stars and compelling them to study their properties in defiance of every obstacle? What was it that im-

[1] London, Jonathan Cape Ltd.; New York, Doubleday & Company, Inc.

pelled Hipparchus to measure the positions and magnitude of the stars—a godless undertaking? What was it that drove men to make long journeys simply to observe an eclipse of the sun? Was it mere inquisitiveness; was it a divine behest; can we throw any light on these questions? Let us at any rate make the attempt.

• I •

THE SUN'S TEACHING

WHEN the last Ice Age was ending in Scandinavia and the Stone Age had come, man became aware that there was another, higher, world outside the familiar one. He was exposed to the influence of this higher world when in the morning he left the cave where he had sheltered for the night, where he had painted animals of the chase on the walls and made offerings of the bones of bears and bison. Time was meaningless in the cave. When he left it he became aware of life, of its fulness and change. Animals and plants aroused his desires or his fears. The movement of the shining sun and the luminous moon gave him the means to measure time. Occasionally he was seized by panic when the bright sun suddenly grew dark in a cloudless sky. If the darkness grew more intense, so that the birds stopped singing and flying, and began to roost, while other animals became restless, their fear was communicated to man; and this fear became the more intense the more rapidly the darkness increased, causing actual panic in certain species. Eventually, when instead of the sun only a shining ring was visible in the sky, he felt that disaster was approaching; he screamed with terror and only began to breathe when at last the sun reappeared. Like so many of the animals, he knew that this waning of the sun's light was something different from what happened at sunset; a fixed rule had been broken. At this point man became aware that he was living in a world governed by order. But ages passed before this awareness was reached. Some adapted themselves to the alternation between day and night, but were afraid to look at the heavens and to study the movements of the luminaries. With others, the daily movement of the sun became something instinctive so that the sun's position allowed them to tell the time. Karen Blixen tells

in her book *Out of Africa* how the negroes in Nairobi used to gather to hear the cuckoo clock strike twelve:

'Its apparition was every time a fresh delight to the young people of the farm. From the position of the sun, they judged accurately when the moment for the midday call was due, and by a quarter to twelve I could see them approaching the house from all sides, at the tail of their goats, which they dared not leave behind . . . the bigger ones were about ten years, and the youngest two years.'[1]

Some people use the position of the sun as a compass and acquire an astonishing degree of accuracy. According to certain scientists the bees do the same.

The number of peoples taking no interest in the heavenly bodies is small, and they are the most primitive. Some hunting and fishing tribes take little interest in the sun; others regard it as a living being and establish a connection between it and the moon. The seasons are observed but are not generally linked with the sun. An exception is formed by the Eskimos and certain Indians on the North-West coast of North America who are aware of the solstices and possess a calendar.

The ideas of the navigators among the South Sea Islanders can be gathered from the story how Maui was victorious over the Sun God Ra:

'Maui had revealed to mortals the secret of fire and he had raised the vault of the heavens; but a third great task still remained. The Sun was capricious and unreliable. Every day it set at a different time, as might suit it, and people found it impossible to tell the time by it. Often, long before the day's work was over, when food was still cooking in the oven and the psalm of prayer had not yet been sung to an end, people suddenly found themselves in profound darkness.

[1] New York, Random House, Inc.

'Maui resolved to apply a remedy. Now Ra is a living being and full of divine power. He is of a terrible strength; in shape he is like a man. In the morning and in the evening he spreads his golden locks along the sky. Buataranga advised her son Maui to have nothing to do with Ra; many had tried to regulate his course but none had succeeded. But Maui was full of confidence and not to be dissuaded. He was firmly resolved to make Ra his prisoner and force him to obey.

'Maui thereupon took strong coconut fibre and made of it six stout ropes; each rope had four strands. These ropes he named "kingly snares". When they were ready he carried them to that distant opening in the earth's surface through which Ra mounted each morning from Avaiki into the sky. Here he placed the first of his snares for Ra. Some distance further along the sun's course he placed the second snare, and so with the others, all along Ra's path.

'Early next morning Ra rose unsuspectingly from Avaiki to make his daily journey through the sky. Maui lay hidden near the first snare waiting for him and gleefully drew it tight; but it slipped down Ra's body and only caught his feet. Maui ran hastily to the second snare, but this one also slipped and only caught Ra around the knees. The third caught him around the hips, the fourth round the trunk and the fifth under the arms, and still Ra continued headlong on his course, hardly noticing Maui's devices. At last, fortunately for Maui, the sixth and last of the kingly snares held Ra around the throat. Maui hauled the snare tight while Ra was struggling desperately for his freedom. But in vain; Maui pulled the noose so tight around his throat that he was almost throttled. Finally, he made the rope fast to a rocky protuberance.

'Ra realised that he was beaten and to save his life readily promised Maui to be less impetuous and more reasonable in future in his daily journey across the sky, and to leave people plenty of time for their daily business.'

In agricultural communities people have always been accustomed to observe the sun's daily and annual course. To them the

sun is the great Deity, the author of life and prosperity. This belief was spread among civilised peoples, e.g. the Egyptians, Babylonians and Chinese at the time when the earliest written records were made. The following Imperial Decree goes back to the beginnings of Chinese history:

'Thereupon he gave orders to Hi and Ho, to contemplate with reverence, to calculate and to represent the Sun, the Moon, the Stars and the positions of the Sun so that men might reverently be allowed to know the time.

'He appointed Hi, the middle one, to dwell in Yü I, which is called the Bright Valley, there honourably to salute the rising sun and accordingly to distribute and order the labours of the East (the Spring). The day is of medium length, the constellation is that of the bird.

'According to this the middle of the Spring can be accurately computed. Men go to work, the birds hatch their eggs, and animals mate.

'Further he ordered Hi, the third one, to dwell in Southern Kiao, to distribute and order the formations of the South (the Summer), and to act reverently in accordance therewith. The day is at its longest, the constellation is that of fire. Midsummer can be determined from this. Men are restless, the birds moult, the fur of animals is thin.

'Further he appointed Ho, the middle one, to dwell in the West, which is known as the Dark Valley, to give honourable conduct to the setting sun and to distribute and order the fulfilment of the West (of Autumn). The night is of medium length, the constellation is that of the hole; this allows the middle of Autumn to be observed. Men are brisk and cheerful, birds grow their feathers and animals their fur.

'Further he appointed Ho, the third, to dwell in the Northern place which is called the Dark City, to distribute and observe the changes of the return. The day is short, the presiding star is that of the morning (the Pleiades); this allows the middle of winter to

be determined. Men are in their homes, birds have thick feathers and animals heavy fur.'

Saluting the Sunrise

Observant men could not fail to notice how life awakens after the chill and darkness of night. Many animals stretch themselves and utter their cries; the birds begin to sing. Men awaken and follow their occupations. The warmth-giving sun is noted and saluted. Red Indian mothers hold their newly-born babies out to the sun. Among the Navahos the young girls reaching the age of puberty have to prepare a huge cake; while it is baking they have to run towards the rising sun and back, wearing full ceremonial dress.

Saluting the rising sun was a common practice. Greeks like Socrates and Dion followed it; so did the Chinese, the Japanese and the Indian Brahmins. The Jewish historian Josephus, writing in the first century A.D., reports that the Essenes worshipped the sun in a special way: 'Before the sun rises they pronounce no unhallowed word, but address to it certain ancient prayers as though to beg it to rise.'

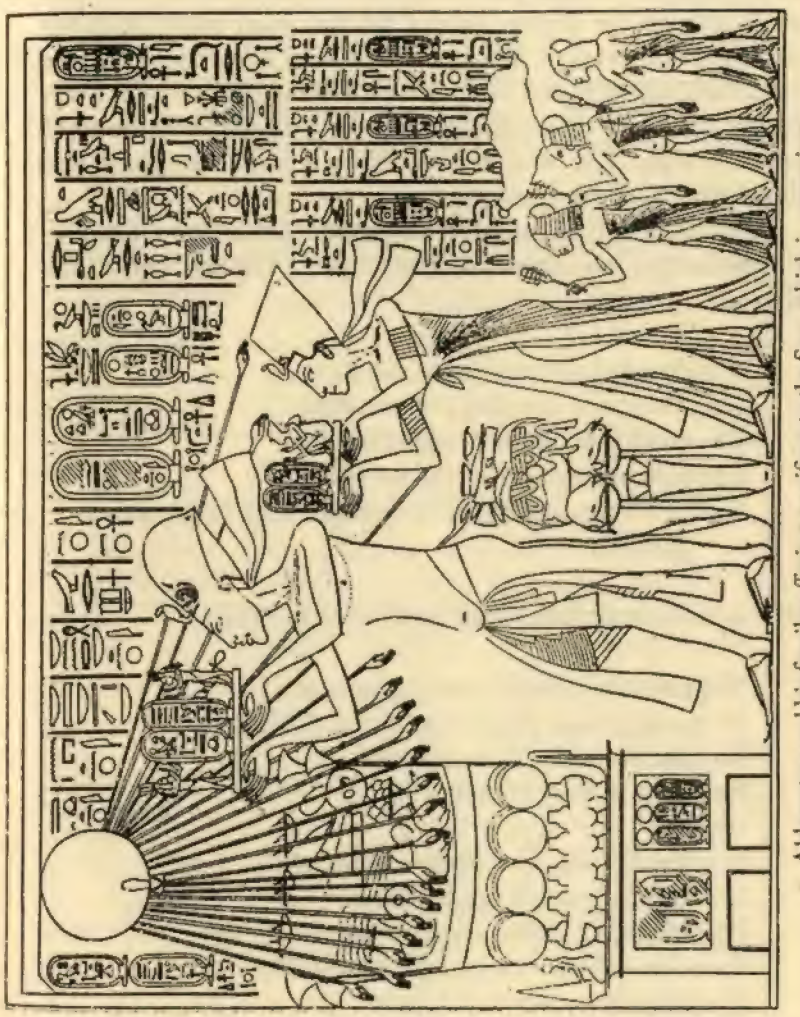
Sun worship constituted a grave danger for the Jewish and Christian religions. In 592 B.C. the prophet Ezekiel (VIII, 16) reproved the Jews of Jerusalem for worshipping the rising sun with their backs to the portals of the Temple; similarly in A.D. 500 Pope Leo I in a Christmas sermon criticised the Christians' malpractice in saluting the sun on its rising while turning their backs on St. Peter's. Even in the twentieth century Christian Macedonians greeted the rising sun by bowing down and crossing themselves; Christian Eskimos had a similar practice. In Siam the Kha daily 'place a basketful of rice in the sunlight, a sort of embarrassed homage', while in Persia the priest of the sun greets the rising sun with flowers and a beaker filled with water. The Kurdish devil-worshippers, the Yezidis, turn towards the rising sun, kiss the tips of their fingers and raise their hands to their forehead.

The most impressive worship of the rising sun was that of the Egyptians (Fig. 2). Amenophis IV wrote, in 1375 B.C., a song of praise which his subjects recited as the sun rose (Fig. 3):

'You appear in your loveliness on the horizon
Living Sun who are as old as life.
You are on the Eastern horizon and have filled all lands
With your beauty.
Your rays clasp the lands as far as the end
Of all you have created.
You humble the lands for your beloved son
King Akhenaton . . .
Your light shines in the early dawn
And you shine all day in the likeness of the Sun.
The two continents are in festive mood.
Men awaken and rise from their beds,
They wash their bodies, they put on their clothes.
They raise their arms and worship because you have appeared.
All people go to their work
The cattle fill themselves with grass
Trees and herbs flourish
The birds fly from their nests
They raise their wings in worship
All wild things leap to their feet
All things that fly high or low
Live, now that you have shown your light to them again.'

In the fifteenth and fourteenth centuries B.C. Egyptian artists created figures of dead persons worshipping the rising sun. A vertical plaque facing them is inscribed with a song of praise. The figures stood in a niche, facing the East, within the tomb.

At a later stage sun-worship was taken over by the Romans. The Roman Emperors liked to have themselves represented on their coins with their heads surrounded by the rays proper to the Sun God; this practice continued until Constantine the Great.



2. Akhenaton and his family offering sacrifices to the Sun, which is scattering its gifts with open hands

Julian the Apostate even tried to restore sun worship to the place it had lost to Christianity as the official religion. In this connection he wrote a song of praise to the Sun to this effect: 'When the cock, sensing the sunrise, salutes the Sun even before men say their morning prayers, he proves himself to be a member of the sun chain; and the power of the god to whom he calls is, as it were, present in him.' At a lower level the heliotrope replies to the god's heavenly song. The invincible Sun King is praised as creator and director of the divine harmony.

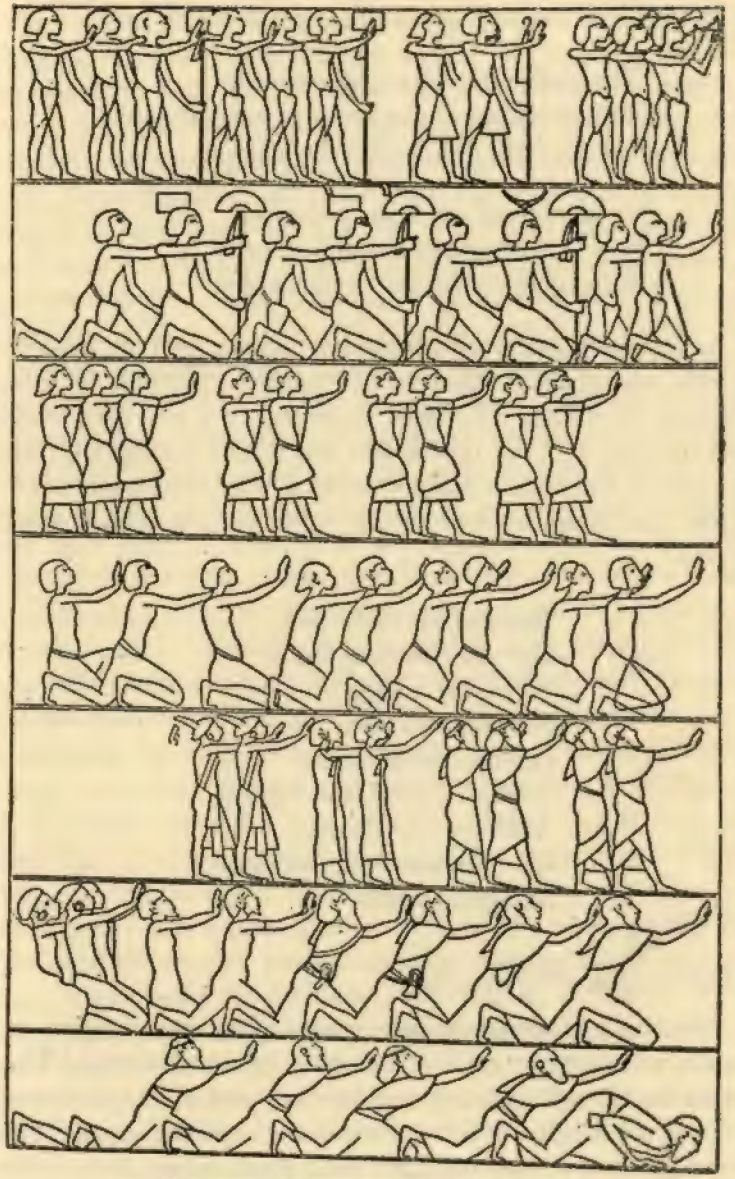
The way in which medieval Christians looked upon the sunrise can be illustrated from a number of texts. The first was written about A.D. 900:

'Phoebus has not yet risen in radiance,
Only Aurora is dawning over the earth.
The watchman calls to sluggards: Arise.
The light of dawn lies on the sea mist;
Behind the mountains and the light the sun's bright glance
shines.'

Here is St. Francis' song to the Sun (*circa* A.D. 1224):

'Highest omnipotent Lord of goodness
To you be praise, glory, honour and all blessing.
To you, Almighty, these belong,
No man is worthy to name you.

Be praised, Lord, with all your children
And especially our Sister, the Sun,
You kindle her for us in the daytime,
She is fair and shines with a great radiance,
She brings news of you, Almighty.
Be praised, O Lord, for brother Moon and the stars,
You have formed them in the heavens,
Clear, precious and bright.'



3. Akhenaton's subjects worshipping the Sun

In 1666 Paul Gerhardt wrote this poem about the sun:

'The golden sun full of joy and bliss
With its radiance brings to us in our narrowness
A lovely light that rejoices the heart.

My heart and limbs were lying low.
Now I am standing brisk and cheerful
With my face turned towards the sky.'

Incantations also were practised at sunrise. In 1527 Johannes Carion sent to Duke Albrecht of Prussia instructions for interrogating the spirits. The right thumbnail of a boy aged twelve was anointed with fine oil, his face was turned towards the rising sun and an incantation was pronounced. The incantation uttered before sunrise by Kepler's mother when her son was ill is well known:

'Sun and day of the Sun
Give a welcome to God.
You come riding;
Here stands a man;
Let him beseech you
Father, Son and Holy Ghost
And the Holy Trinity:
Give this man flesh and blood
And good health.'

The Four Quarters of the Sky

When men observed the daily course of the sun along the sky they saw it rising in the East, bringing light and warmth. They found the warmth growing until the sun reached its culminating point in the South, and felt it diminishing until the sun set in the West. In other words, they observed a great system: the awakening of life in the East, its climax in the South, and its disappearance

in the West. This gave them the significance of three great quarters. The North provided the fourth—the region where the sun was never seen. On the other hand, the stars were observed there at night; and the stars were always present. The North, too, was therefore an important quarter of sky and earth. Life and death, the strength of life and eternal rest—these were appropriate to the four quarters, and a wise man would follow their ruling. Hence the grandiose manner in which the Egyptians observed the four quarters. Their burial places were arranged to allow the dead man to look towards the East (the rising sun) while his dependants prayed looking towards the West (the entrance to the kingdom of the dead). Special attention was paid to the four quarters in the construction of the great pyramids, about 2800 B.C. The Great Pyramid of Cheops, despite its size, is orientated so exactly that its edges diverge from the four main points by no more than three minutes. The pyramids are gigantic tombs; they are approached from the North. On the Eastern side of the Great Pyramid of Cephren the giant figure of the Sphinx is on guard—the couching lion with Pharaoh's head. It is of the same age as the pyramids; it formed the valley gate to the burial place of Pharaoh and was dedicated to the Sun God, Ra. After this period sun worship became the official religion. About 2700 B.C. Neuserré erected a huge Temple at Abusir in honour of the Sun God, with a length of 109 metres, its main gate, altar and obelisk having an exact East-West orientation. South of it the Ship of the Sun could be seen, also lying East and West. About this time the city of the sun (Heliopolis) was founded, where the priests were greatly respected at the time of Herodotus. Later Amenophis IV tried to make sun worship the exclusive state religion, but failed; other gods, particularly Osiris, the god of the dead, continued to be worshipped. When Seti I founded a temple about 1300 B.C. he made the goddess of wisdom address the king thus: 'The hammer in my hand was of gold when I hammered the peg, and it was you who held the cord. Your hand held the spade when its corners were fixed in accordance with the four pillars of heaven.'

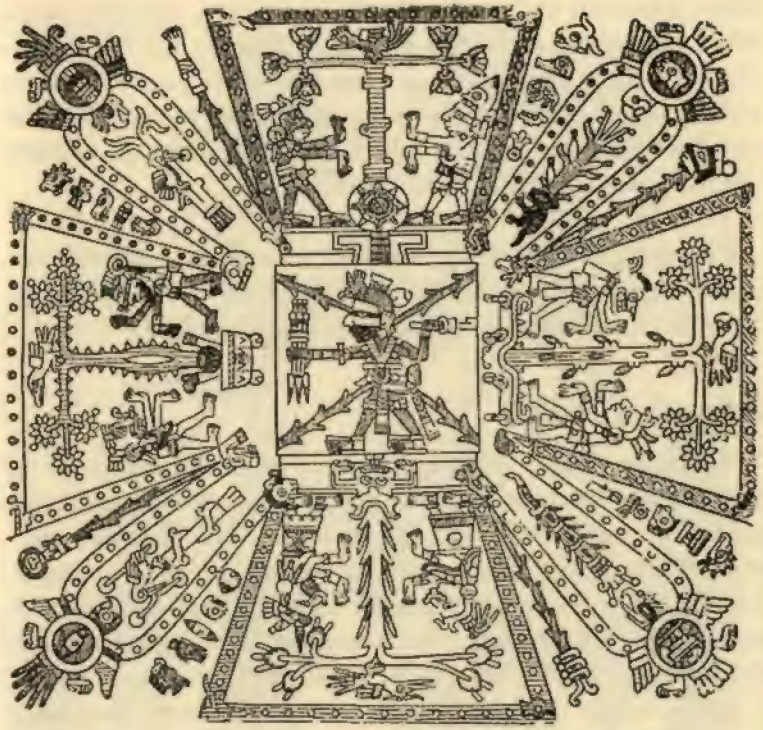
At a much later stage the Great Bear was used for purposes of orientation. Thus in 237 B.C. when the foundation stone of the new temple at Edfu was being laid, the king declared:

'I grasp the staff of my flight, I grip the handle of the hammer, I seize the cord together with the Goddess of Wisdom. I turn my face towards the motions of the stars. I direct my eyes to the constellation of the Bull's Thigh (the Great Bear). The Sk-'h'w is standing along my measuring instrument. I determine the corners of your temple.'

The same practice was followed at the time of Augustus, when the temple of Dendera was being re-erected. In each instance the rising of the middle star of the handle of the Plough (or Great Bear) was apparently observed. This rising occurred East of North, and consequently the deviation of the axis of the temple is 3.5° at Edfu and 8.5° at Dendera.

Similar procedures were followed elsewhere. In Mesopotamia a temple of the sun existed where Shamash was worshipped. In these buildings, however, the four quarters were not strictly observed; in China, on the other hand, we still find a strict observance. It arose out of the ancient Chinese belief that the Emperor of China, being a son of heaven, derived his power from the god of the heavens who was enthroned at the celestial North Pole; the emperor, therefore, as vice-regent of God, was required to look towards the South. Accordingly the emperor and his representatives look Southward, whereas petitioners look towards the North. These beliefs led to a strict observance of the four quarters in China, and this in turn was reflected in the orientation of temples and public offices as well as of important streets, for instance in Peking. The rule was so rigid that even Buddhist temples were constructed on a North-South axis, so that the faithful reached the great temple walking from South to North.

The most impressive embodiment of this principle is the sacrificial precinct of the Temple of Heaven in Peking. Here a road runs due South and North; along it are situated the great circular



4. Ancient Mexican cosmogram

temple and the circular hill where the emperor sacrificed, particularly in the night of the winter solstice. Sacrifices involving East-West orientation play an unimportant part relatively to this major celebration. Evidently this practice is extremely old; it probably existed in the third century B.C. The observation of the North-South line seems to have spread gradually from China across Northern Asia, and into Northern Europe.

In India the four quarters were strictly observed at the beginning of our era. Their significance can be described as follows:

'If the altar was not constructed in exact conformity to the prescribed shape, if one edge was not exactly at right angles to an-

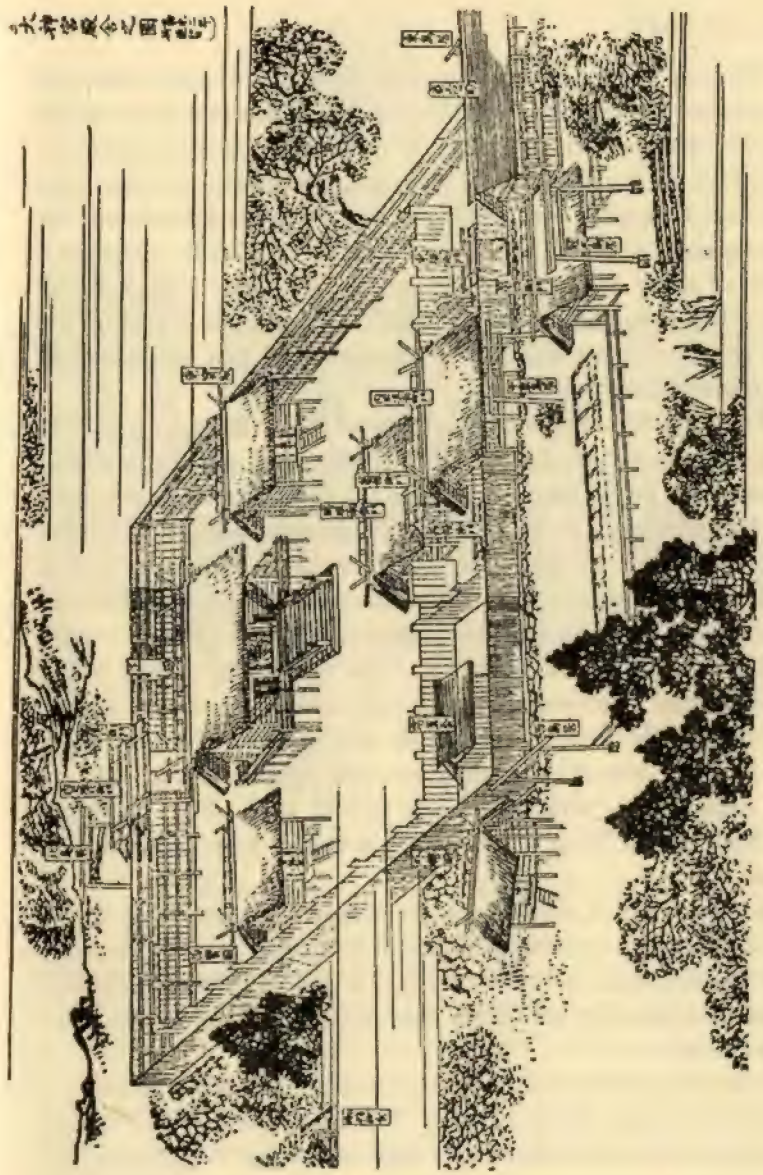
other, if an error had occurred in the orientation, the deity would refuse the offered sacrifice—a dreadful thought for the Indians who regarded every sacrifice as a regular contract, a sort of barter with the appropriate deity who was not bound to fulfil the wish connected with the sacrifice if he rejected the offering.' (Zinner, *Geschichte der Sternkunde*, Berlin, 1931.)

Cosmograms were frequently constructed, i.e. pictures containing the four (or eight) main points of the compass; this occurred for instance in China, Tibet and Mexico (Fig. 4).

Orientation of Tombs

We observed above that a rigorously exact observation of the four quarters was relatively rare; generally an approximation sufficed. This applied even more fully to tombs. The Christian cemeteries were generally arranged so that the dead person lay along an East-West line, looking towards the East. This practice was common in Europe even during the Bronze and Iron Ages, i.e. before the introduction of Christianity. A fair number of tombs exist, however, where the body lies along a North-South line facing South. In the Sudan and near Dacca dead persons are buried along a South-North line, but they face towards the East. This may be due to ancient Egyptian influences; the bodies of the Pharaohs lay along a South-North line and were provided with a sloping exit towards the North, allowing the soul to fly to the eternal stars situated at the celestial North Pole. After the 6th Dynasty the exit was moved to the East so that the dead Pharaoh should be able to see the rising sun. In Southern Arabia the quadrilateral temple at Hugga (dating from the third millennium B.C.) has its sides parallel to the North-South and East-West axes, with an entrance at the East; this too may reflect Egyptian influences.

More primitive peoples do not observe the four quarters in the construction of graves; at most they place the body so that it looks homeward.



5. Temple of the Japanese Sun Goddess at Ise

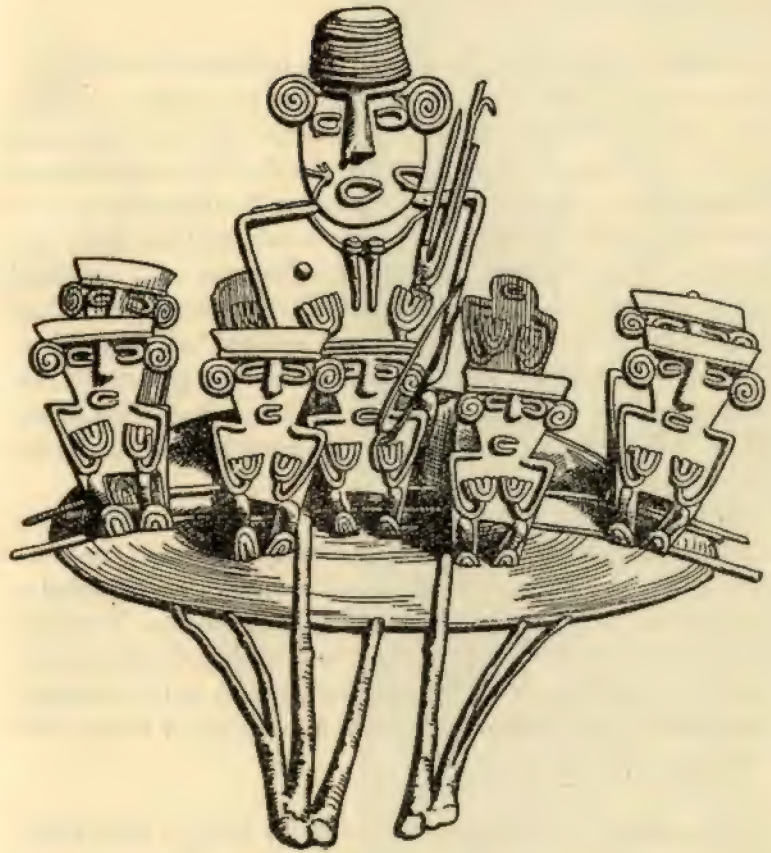
The Sun God

The sun was frequently imagined to be a god; sometimes also a goddess. This was the case in Southern Arabia where, about the beginning of our era, the temple Dhāt Ba'dān existed. In Japan the temple of the Sun Goddess, Amaterasu, has been in existence since the fourth century B.C. (Fig. 5). According to Herodotus, the Massagetae sacrificed horses to the sun. For similar purposes a flock of sheep dedicated to the sun was probably kept at Apollonia. Herodotus in mentioning this also relates that 'a table of the sun on which roast meat which anyone might take stood outside the gates of Carthage'.

Among a number of peoples special times were set aside for prayer in the course of the day. The Manicheans turned their faces towards the sun in its course across the sky. The Sabians in Harran offered prayers to the sun at its rising, at noon and when it set. The practices were elaborate. Morning prayer was held before sunrise at the upright Post of the East; the worshippers inclined themselves eight times, prostrating themselves three times at each inclination. Prayers began half an hour before sunrise and ended at the actual moment when the sun rose. The second prayer was held at the Post of the Middle of the Sky and began when the sun had just started its downward course; it consisted of five inclinations with three prostrations each. The prayer at the Post of the West which ended at sunset followed a similar ritual.

In America, too, the sun was worshipped as a god (Fig. 6). In Mexico the great pyramids of the sun and moon were constructed near Teotuhuacan in the first century A.D. Among the Aztecs and Mayas sun worship continued after A.D. 1000. Human sacrifices were offered.

In South America the great religious buildings near Tiahuanaco were constructed about A.D. 600. The uncompleted Gate of the Sun shows at several places the image of the Sun God. Later, the Incas built a great temple at Cuzco, and erected symbols of the



6. Ancient Peruvian Sun God, with worshippers

moon and the stars as well as a golden disc to represent the sun. At the Feast of the Sun the Inca (the 'Son of the Sun') caused these images to be carried to a plain lying East of the capital where they were placed on certain rocks. The Inca Pachacutic (1430–71) had stone pillars erected to measure the height of the sun. The equinoxes and solstices were not observed; but the period for sowing the crops was determined.

Representations of the Sun

As early as the Stone Age the sun was represented as a disc between a ram's horns. Bulls also were treated as peculiar to the Sun God. Later, among the Egyptians, falcons were the specific sun animals, and jaguars among the Aztecs. In the Bronze Age (second millennium B.C.) the sun was represented in Northern Europe as a great disc which was carried about in a cart on feast days. The temple of the Sun God at Sippar (first millennium B.C.) contained a great disc with a four-rayed star in front of the image of the god; this disc stood vertically on a low bench and was held from above. The same arrangement was probably used for the golden sun disc in the temple of Cuzco and for the great stone altar of the Aztecs (Plate I). It shows the Sun God in the centre surrounded by the gods of the four proto-suns.

Symbols for the sun were commonly used, e.g. multi-spoked wheels, discs, or the swastika. The swastika indicates the sun's movement. This movement—from left to right—was regarded as harmonising with the sun and therefore as propitious. Hence the practice of riding three times around the church in the direction of the sun on the days of St. George, St. Leonard and St. Stephen. The contrary direction was regarded as unlucky. A Frisian folk tale brings this out:

'Once upon a time a young girl went to a witch to learn witchcraft. Already she could make mice without tails. When the parson found out he made the girl walk three times around the graveyard following the direction of the sun and praying. In this way her witchcraft left her.

'Once upon a time there was a strict father who had a little daughter who had to say her prayers every evening before she went to bed. One evening she said quite a different prayer, and when her father asked where she had learnt it she said: "So-and-So taught me, and if I say this prayer every night for six weeks and then take a black hen and walk with it in my arm three times

11. *The Japanese Moon Goddess Gwaten, showing the hare in the moon*

III. *Japanese animal sequence*

Japanese New Year's sheet for the 'Year of the Dog'

around a church against the sun I shall be able to do whatever I want." The father handed her over to the parson, who questioned her. In three weeks he got her to pray again properly.'

Special significance attached to sunrise on Easter Sunday. Thus the Magdeburg priest, Georg Rollenhagen, author of the well-known satire popular about the year 1595, *The Battle of the Mice and Frogs*, recounts the following story:

'I find it written in ancient books that men should rejoice on Easter Day: like the glorious sun in the heavens which leaps three times for joy early at its rising on the first day of the Easter season, and again at its setting. As it is written in the 19th Psalm: "In them hath he set a tabernacle for the sun, which is as a bridegroom coming out of his chamber, and rejoiceth as a strong man to run a race." Thereupon all folk, both old and young, early before sunrise and later before sunset, hasten abroad in their hundreds to watch the sun dancing. And when they have gazed at it until they see blue and brown, light and dark, spots before their eyes, then one will call out, "Here" and another "There", "Now it is leaping for the first time, now for the second and now for the third time." And if any should say that he had not seen the sun leaping, men would take him for a blind man or a blasphemer.'

This custom—also recorded in England and in Serbia—eventually died out. On the other hand, there were frequent occasions when people asserted that they had seen the sun rotating, for instance at Fátima and Heroldsbach. In 1949 and 1950, on the occasion when children at Heroldsbach said that they could see the sun rotating, it was obscured by thick clouds which made it possible for anyone to claim that he had seen anything. The *Fränkischer Tag* on September 11, 1952, reported:

'Despite warnings by the Church, about ten thousand people went last Monday to the village of Niederhabbach, near Lindlar, where Karl Zianke (a refugee aged 38) claimed to have had his

tenth vision of the Virgin. Zianke's prophecy that the Virgin would on Monday give a sign visible to all was proved false. After the alleged vision distant thunder was heard. At the same time the sun pierced through the low clouds. Although this was a perfectly commonplace phenomenon somebody suddenly exclaimed: "The sun is rotating." Thousands looked at the sky. The crowds broke through the barriers, shouting, "It is turning, it is rotating." . . . A mass hallucination prevailed, and growing numbers insisted that they had seen the sun rotating. When finally yellow spots appeared in the Northern sky, the "miracle" was perfect in the eyes of the crowd.'

Sundials

Observation of the sun in its daily course led to the invention of the sundial. At first horizontal rods were used (gnomons). The Pyramids were employed for the same purpose as early as the third millennium B.C. Many peoples know how to determine the time of day by observing the shadows cast by houses and rocks. To tell the time the ancients employed attractive sundials like the metal diptychs used under the Roman Empire. Towards the end of the Middle Ages sundials using a polar bending style were invented; this also led to the construction of ingenious models. In this way the observation of the sun's course led to an important craft and to fruitful mathematical studies.

The peaks of mountains were also used to determine the time; naturally those lying towards the South were particularly useful. There are numbers of mountains in Europe called Pic du Midi, or something analogous. In the Alps peaks were frequently used to denote the exact hour; such names as Neunerkogel, Elferkogel and Zwölferkogel, etc. (Nine-hour Hill, Eleven-hour Hill, Twelve-hour Hill) occur. The function of a sundial was probably also fulfilled by the Sonnenziel hill near Tennenbach in the Black Forest, which is found as early as 1178 under the form of Sunnencil. The name is probably explained by the fact that, seen from the

Law Court at Keppenbach, the mountain bears 61° West of South, and that the Court closed its business when the sun stood above the mountain. Courts of law were commonly constructed to conform to the four quarters. The stone benches were arranged so that the judges faced East (more rarely West); business began at sunrise and had to be concluded at sunset. The importance of looking East appears also in the orientation of the Lion of Brunswick; this symbol of princely power was set up by Henry the Lion, facing East.

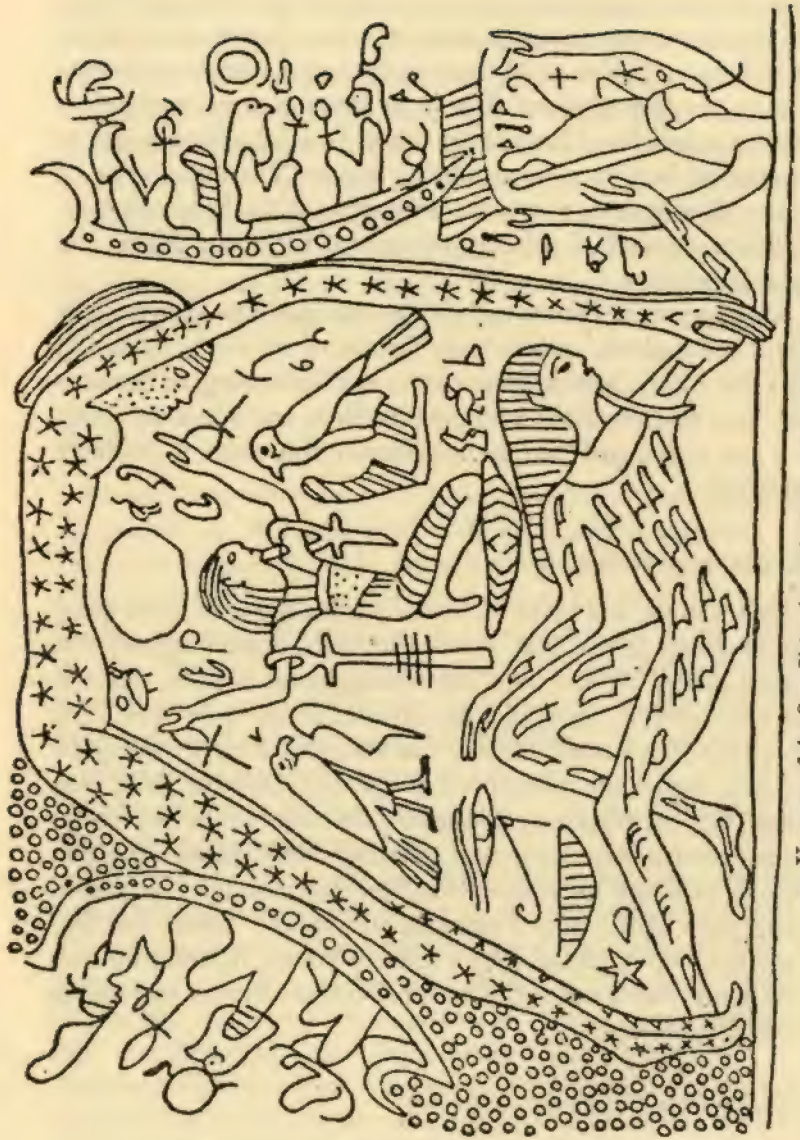
Sun cities were known among the ancients, e.g. Heliopolis in Egypt and Baalbek, with its huge Temple of the Sun in Syria. On the other hand, German place names like Sonneberg, or Sonnenfeld, have no connection with the sun. Here, and where the moon or a star is brought into the appellation, this usage is probably accidental.

The Course of the Sun

How can the sun make its way along the heavens? This question exercised people from the earliest times. Some imagined that a giant carried the sun to its culminating point at noon, where it was taken over by another, who carried it down to the West. The Egyptians early formed the idea that the sun was carried along the heavens, sometimes personified as the Sun Goddess, Nut, in a barge (Fig. 7), eventually diving into the realm of the dead to reappear after a new birth next morning. This voyage can frequently be found in pictures; the Sun Ship is found represented along some of the early Pyramids. Among the Greeks and Romans the Ship is replaced by a team of horses, drawing the Sun God in his chariot across the heavens, an idea common also among the early Germans.

The Divisions of the Year

It was generally assumed that the path of the sun formed a broad band across the heavens, encountering the horizon at the



7. Voyage of the Sun Ship along the body of the Sky Goddess Nut

points where the sun rises and sets at the solstice. The sun follows its daily course along this band, a journey which is longer in summer and shorter in winter. The position of sunrise on the horizon formed an important part in the division of the year into seasons, months and days; it also allowed farmers to determine the seasons of sowing and reaping. In this task the first appearance of the brighter stars at dawn was also of assistance. In Egypt it was the first morning appearance of Sirius which indicated the rising of the Nile and hence the beginning of the floods, and reminded the peasants to be on their guard. Elsewhere other bright stars served as harbingers of the changing seasons. Thus it came about that the observation of the sunrise and of the morning rising of the brighter stars were used to divide the year into months and days. A look at the sky taught men to subdivide the year and the day and thus to lay the foundations of agriculture and trade. A knowledge of the quarters of the sky was also useful in surveying.

The process of dividing the year brought with it the establishment of certain days as holidays. Among these were the solstices. It was generally the summer solstice which was celebrated by dancing and kindling fires at night. This was frequently done on mountains, which accordingly were named after the solstice. In the early Middle Ages many Christians bathed in the sea or in rivers at night or early in the morning—a practice reproved as heathen. Songs were chanted and a loving cup was drunk in honour of St. John, a practice which survived for centuries. At the winter solstice fires were rare. In China the Emperor offered a sacrifice at the winter solstice. The Japanese Nara celebrations are probably derived from this; in both cases the celebration took place at midnight. About the beginning of our era the winter solstice was celebrated at Alexandria on December 25; this was the feast of the Sun God, the 'invincible God'. On January 6, the birth of Aion, the God of Time, was celebrated. These festivals were later taken over and re-interpreted by the Christian Church.

• II •

THE HOST OF THE STARS

AS the sun rises the stars disappear—a phenomenon which continued to strike the imagination of Greek artists. Early vases show the Sun God on his chariot with the quadriga and before him the stars in the shape of boys plunging into the sea; still further ahead the veiled Moon Goddess vanishes into the darkness of the night, while Eos the Goddess of the Dawn takes her place. The dazzling brightness of the sun made it difficult to differentiate between the seasons. The night sky, on the other hand, with the gradual shifting of the rising of the stars, made it natural to use the stars for marking the seasons.

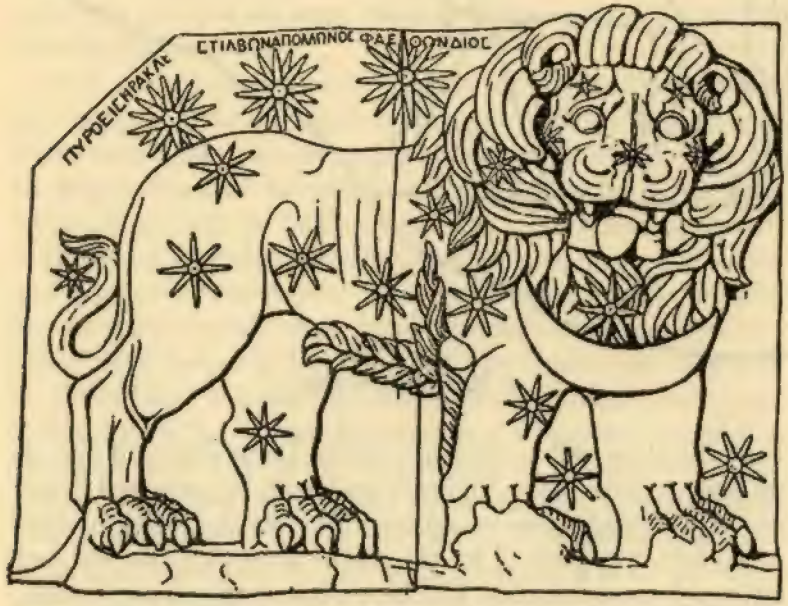
At all times men have been struck by the host of the stars and their regular course along an unchanging track in the heavens. Myths were invented connecting the brighter stars or explaining the origin of smaller constellations like the Pleiades. Lines were drawn connecting the brighter stars and if the resulting figures recalled the animal shapes which men had drawn on the rocks, the resulting constellations were named after these animals. In this process those animals were favoured which were already connected with the sun or the moon, like the Ram, or the Bull and the Cow. There was also the Lion; its divine qualities were symbolised by the Sphinx and by pictures in which the Lion had a star on its chest. The lion was regarded as a symbol of watchfulness and of re-birth. The Sphinx (i.e. a lion with a human head) took over the lion's role; it represented the Sun God. In the Northern skies there was also the Bear, in whose honour sacrifices were made as early as the Stone Age. Gradually constellations were formed from other stars when it became desirable to find a constellation for a given region of the sky. In this way the Zodiac

8. Bull with Sun Disc

was formed, as well as the Circle of the Decan stars and that of the Houses of the Moon. Figures from Greek, Egyptian and Babylonian mythology were transplanted into the sky. Thus Andromeda, who was pursued by the marine monster Cetus and her saviour, Perseus, together with her parents, Cepheus and Cassiopeia, were placed among the stars (Fig. 11). Sometimes it was a courtier's ambition in this way to elevate a ruler to the upper

9. Bulls's head with Sun, Moon and Star

regions. A small group of stars was named Berenice's Lock, in memory of the lock which Berenice placed on an altar when her husband went to the wars. Another small constellation was called Caesar's Throne: it was located at the vanishing point of the comet which had shone at the burial of Caesar. In the same way



10. Constellation of the Lion, with Stars, the Moon, Mercury, Mars and Jupiter

11. Ancient Map of the skies

Bode named a small constellation in the Northern sky Frederick's Glory; Hevelius called another Sobieski's Shield.

The Egyptians attributed special importance to Sirius. Its rising in the morning announced the approach of the Nile floods. The period from this rising until its next morning rising comprehended

the Egyptian year, the length of which could be more easily determined than that of the solar year. With Sirius also the series of the Decan stars begins, i.e. the sequence of thirty-six constellations or partial constellations which span the entire heavens and constitute the sun's path. Sirius follows Orion, the famous constellation with its dagger, nebula and three shining stars. Among the Egyptians Orion was dedicated to Osiris, while Isis was the goddess of his sister Sothis (Sopdet-Sirius). Ancient Egyptian songs mention these two luminaries. 'A song of praise to Sothis the star of Isis, Mistress of the Sky and Queen of the souls of the Gods that rise in the likeness of stars; she shines in the heavens near her brother Osiris, whose path she steadfastly follows.' Isis and Osiris are the most important in the series of thirty-six constellations; the Great Bear (the Thigh of Set or Typhon) was regarded by the Egyptians as the most important constellation in the Northern sky and as the embodiment in the North Pole. An ancient Egyptian text from the Royal Tombs at Thebes runs as follows: 'The four Northern (? spirits), they are the four gods of the servants. They ward off the battle of the horrible one (Typhon) in the sky. He is a great fighter. They seize the forward rope and arrange the after rope on the ship of Ra, together with the sailors who are the Northern Ashemusek, four constellations. Once the constellation of Masheti has been passed, they reach shelter in the centre of the sky on the side South of Sah-Orion, and they turn towards the Western horizon. Now touching the constellation of Masheti it is the Thigh of Set (Typhon). It is placed in the Northern sky, a rope is attached to the two pegs and to the knives in the likeness of a bronze chain. It is the office of Isis in the shape of a hippopotamus to guard the same.'

In China the Great Bear or Wain is worshipped as a propitious deity. Women who wish to have children pray to it. A bridal crown displays the Great Bear in pearls and emeralds. An ancient Chinese picture of the Han dynasty (about the beginning of our era) shows the Great Bear as a ruler in a chariot with various spirits doing homage.

The following folk tale is recorded in Pomerania:

'The Great Bear is also called Dümkt. Dümkt was a wicked farmer who used his people and his cattle most cruelly. As a punishment he was placed in the heavens after his death. There he drives in the same wild way he had when on earth. Three horses draw his wagon, and Dümkt rides on the middle one, but the whole group is all awry, as though it were about to fall over any moment.'

This Hans Dümkt, also known as the Little Rider, is shown on a woodcut dated 1532.

The other seven-star constellation, the Pleiades, caught the attention of many nations and found a place in mythology. This constellation becomes invisible at times. A Danish folk-tale explains this as follows:

'Once upon a time there was a girl who had seven illegitimate children. A man met her and said to her: "Good-day to you, you and your seven bastards." To punish him God changed the man into a cuckoo. The children were turned into angels and placed in the sky.

'During the season in summer when the cuckoo calls the Pleiades are invisible.'

Different views about the Pleiades were held by the Ancients. One of its seven stars is of low magnitude and therefore rarely seen, a circumstance which Ovid explains as follows:

'When night is over and the sky grows red
The birds, touched by the dew, begin their plaintive song.
Then the traveller after a night's march lays aside the half-burnt torch
And the peasant goes to work again.

Then the constellation of the Pleiades begins to raise the burden from the father's shoulders;
Some give their number as seven; others, more commonly, as six.
One reason is that only six of them reached the embraces of the gods,
(Alcyone, together with Celeno, was wedded to Neptune
While Taygete, together with Electra and Maia
Won the love of Jupiter while Sterope won that of Mars.
But the seventh, Merope, became the bride of a mortal, Sisyphus.
This is why she hides from our eyes in shame.)
Another reason given is that Electra cannot bear her grief
Over the ruins of Troy and puts her hand before her eyes.'

The Milky Way has the appearance of connecting a number of stars. Chinese and Japanese myths record that Tanabata, the woman at the loom (Vega) is connected by means of the Milky Way with her shepherd lover (Canopus), but is allowed to visit him only once each year; hence the feast of Tanabata.

Tanabata was the name of a weaver; the story tells that after she had married the shepherd Hikoboshi, her former zeal in weaving robes for the god of the heavens dwindled; in punishment she was transplanted to the other end of the sky. Only once a year, on the seventh day of the seventh month, the god permits them to stay together. To celebrate this annual wedding bamboo plants are placed before the houses.

The constellation in which the Chinese grouped the stars were entirely different from those of Egypt and Asia Minor. The god of the heavens was imagined as ruling at the North Pole; accordingly those constellations which are visible throughout the year are appropriated to the imperial offices. The other constellations correspond to objects of commerce and agriculture.

Nut, the Egyptian goddess of Night, was depicted since the earliest times as wearing a robe of stars. She appears in this way on

sarcophagi, where the Decan stars and the constellations around the North Pole are also shown. Egyptian temples of the last century B.C. show the sky with its constellations on their ceiling. At this time the Greeks began to determine the position of the stars. Celestial spheres were constructed, with the stars and constellations inscribed on them; exact location took the place of guesswork. This was the beginning of a scientific study of the stars' positions and magnitudes.

Nut was not the only goddess to be shown with a robe of stars. Naturally enough, rulers and princes, the deputies of the gods, wore a ceremonial attire of stars or caused their coronation robes to be decorated with the signs of the Zodiac. This practice was taken over by the Roman and later by the Byzantine Emperors, whence the custom reached Christian Western Europe. Of these coronation robes the most famous is that of Henry II. It was made specially for him, and shows a number of pagan constellations as well as Christian figures.

Among the morning risings of the stars that of Sirius, which was of such importance to Egypt, gradually came to be studied to the exclusion of the others. The rising of the other stars was important only to astrologers, except at sea, where the risings of the stars were always important, particularly in regions near the Equator. The inhabitants of the South Sea Islands, for instance, make skilful use of the stars for navigation in this region. The paths of the stars are almost vertical there, and consequently it is easy to memorise the consecutive stars of the constellations as they rise, and thus to follow a course at sea.

• III •

THE DANCE OF THE STARS

The Moon

THE sun and the stars present the very embodiment of order. Unceasingly and along unchanging courses the stars move around the earth, and the daily course of the sun also follows the circumference of a circle. This movement around the earth is repeated without end and has always created a deep impression on men. It caused them to believe in the existence of a god of the sun or of the heavens, contemplating and guiding all things and desiring the celestial order to be applied to the earth where disorder rules to the confusion of mankind. It was the business of rulers and priests to ensure that the divine behests were followed on earth. In this way empires arose which seemed destined to last for ever. The orientation of tombs and temples and even of official buildings, together with the observation of the seasons and of kindred processes was exactly prescribed. This form of worship and this view of celestial events were rigid and could hardly have led beyond an understanding of the circular movement of those bodies. The whole system of ideas became fruitful only when other celestial bodies, chief of them the moon, came to be observed. The moon, too, moved across the sky among the stars, which it overtook night after night, while its appearance underwent a mysterious change from the feeble sickle in the evening sky to the shining disc of the full moon dominating the night and illuminating the earth until it began to wane and turned again into a narrow sliver which vanished at dawn. This process continually repeated itself in a cycle apparently equivalent to the menstrual period of women. Marvellous indeed was the moon, with its surface showing a number of dark spots which gave rise to a series of different inter-

pretations. Some saw in it a crouching hare (Plate II), others a human face; others again a number of leaves, as is recorded in a South Sea Island folk-tale:

'Blind Kui had four charming daughters, of whom Ina was the oldest. Marama (the moon) had often admired her at a distance, and had fallen so much in love with her beauty that one night he left his place in the sky to carry her home as his wife. The never-resting goddess Ina became a model spouse. On clear nights one can plainly see a great heap of leaves in the moon; these leaves she uses to cover her never-empty oven; one can also see the tongs made of a split branch of coconut palm which she uses to arrange the blazing coals without burning herself.'

The moon evidently rules the night; it brings with it the nightly chill and dampness. This is why the Thessalian witches invoked at night the dripping moon with its human face.

Others saw in the moon a good-natured old man who helped lovers to marry happily. The Chinese have a story dating from the eighteenth century (*The Red Chamber*, p. 444).

'Yes, my dear, if the old man in the moon wants it, lovers will marry even if they are a thousand miles apart. The old man picks his favourites in secret and ties them together with the magic red thread which he winds around their feet. Even if continents and oceans and years are between them, in the end the two must become man and wife. No human wish can stand against him. On the other hand, even if a couple are close neighbours and their parents and relatives have solemnly promised them to each other, they will never get married unless the old man in the moon ties his red thread.'

A very different view of the moon was taken by the German poet, Hugo von Blomberg (1820–71). This is what he wrote:

'The moon rises late, it stares at me
Through the low scrub.
Its face is red and looks wild and awry
As though it had been drinking and fighting.'

The sun and moon are the two chief deities in the sky. The Vedas say: 'The two young players come with their magic to the sacrifice, to the East and to the West; the one contemplates all the worlds, the other is reborn to measure the flow of time.' Some also regarded them as being siblings, or spouses. When, as sometimes happened, the moon eclipsed the sun, the moon was rarely blamed. The usual cause was seen in an evil spirit, to be expelled by shouting and other noises. During the eclipse of the sun on April 30, 463 B.C., Pindar wrote an ode praying the gods to avert evil.

The unceasing spectacle of waxing and waning provided by the moon proved more fruitful than that of the sun's daily course. Men learned to use the moon as a measure of time. Later it was used to sub-divide the year. It was assumed that normally twelve cycles of the moon made a year; eventually, however, it was found that this was incorrect, and that from time to time a thirteenth month had to be intercalated. In other words, the apparently exact relationship between years and months was incorrect. The thirteenth intercalatory month was looked upon as improper; hence the number 13 was regarded as unlucky.

We saw that the sun was worshipped; so was the moon, as a god as well as a goddess. In Mesopotamia a ziggurat (a tower arranged in tiers) in honour of the moon god, Nannar, was erected about 3000 B.C.; it was permanently kept in good condition until the time of Cyrus, about 500 B.C. Within the precincts of this temple another was erected by King Bur-sin in honour of the moon goddess, Nin-gal, about 2200 B.C. In all parts of the world the moon was worshipped by saluting the new moon and celebrating the full moon. The only peoples not to observe it are primitive Greenland Eskimos and certain South American Indians. Moon worship repeatedly found its way to Egypt, and rivalled the

IV. *King Meli-Sipak II, with his daughter, facing the Goddess Nanna. Above, symbols indicating Venus, the Moon and the Sun*

v. *Intaglio with comet and constellation of the Lion; also denarius, showing Caesar's Comet*

vi. *The Comet of 1577 above Nuremberg*

Alarm and despondency caused by the Comet

VII. *Street astrologer*

senior cult of the sun. In Harran, another centre of sun worship, a moon cult had a long history. The famous ancient Temple of the Moon near the Raqqa gate was destroyed by the Egyptians in A.D. 1033. At the Kadi Temple a moon feast was celebrated on the 27th of each month, as late as the first millennium A.D. At Mecca, the home of Mahomet, there was a Temple of the Moon God, Hobal —the Ka'ba, containing the famous black stone.

The moon's light is feeble; accordingly it is possible, as it is not with the sun, to determine exactly the course of the moon across the sky; this is marked by twenty-eight constellations known as the Houses of the Moon. For the sun—once an average period of thirty days had been accepted for the month—twelve stages were laid down bearing the names of adjacent constellations: the Ram, the Bull, the Twins, the Crab, the Lion, the Virgin, the Balance, the Scorpion, the Archer, the Goat, the Water-Carrier and the Fishes (Fig. 19). These divisions of the Zodiac into twelve equal parts or signs was maintained even when the equinoctial position of the sun was displaced through the phenomenon of precession. In the Far East a series of twelve animals exists (Plate III, 1) beginning with the Rat and ending with the Pig; it serves not so much to sub-divide the sky as to divide the lapse of time into twelve consecutive years (Plate III, 2), months and double hours.

The credit for having studied the course of the sun and the moon and for having ventured to foretell eclipses belongs to the Babylonians. A report by the Court Astronomer Balasi to the King (in the seventh century B.C.) deals with the prediction of eclipses, and his attempts to observe them: 'As touching the eclipse of the sun, of which my Lord the King spoke, the same has not occurred. On the 27th I shall again examine the skies and report.'

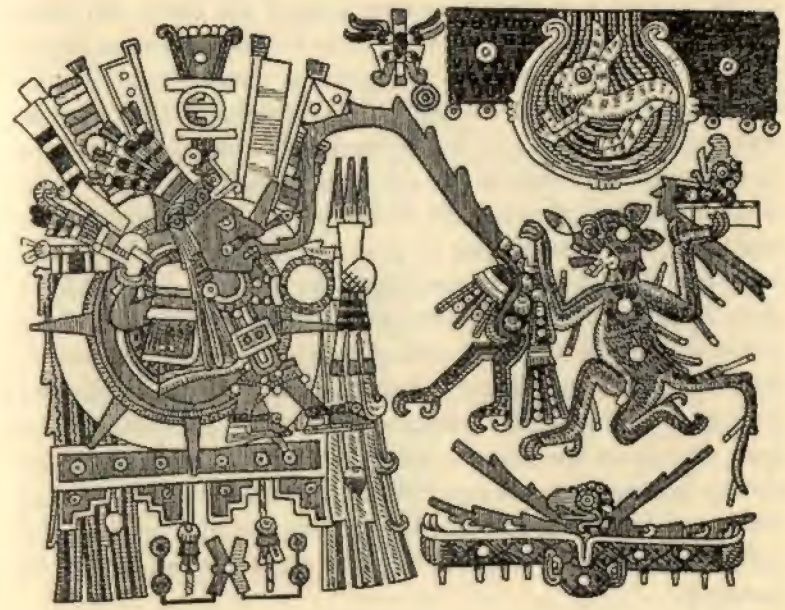
The Planets

If the sun and moon alone existed apart from the stars, their movements among the stars would presumably have been ob-

served and interpreted. Even the most difficult calculation, the prediction of eclipses, was attempted; from the vague belief that a ring around the moon foretold an eclipse observers proceeded to the certainty that an eclipse depended solely on the respective positions of the sun, moon and earth, and could be calculated in advance. Yet even then no real progress would have been made in observation and interpretation. A genuine advance became possible only when the planets (or wandering stars) like Venus and Jupiter struck observers by their brightness. Their behaviour aroused the observers' interest. They do not always move straight ahead, like the sun and the moon; occasionally they stop or move backwards until, as though moved by an invisible hand, they decide to move ahead again. Moreover, there was a great variety among their movements: Venus and Mercury seemed to dance around the sun; others, like Saturn, Jupiter and Mars, appear in the East in the morning, then dominate the entire night; in a third phase they are seen disappearing in the evening sky. Their behaviour was thus entirely different from that of the sun and the moon and gave rise to new questions and interpretations. People were fond of tracing a similarity between these planets and the vicissitudes of human life. An early interpretation (made in 1970 B.C.) runs as follows:

'When Venus stands in the East on the 6th of Abu, there will be a downpour from the heavens; there will be destruction. She stands in the East until the 10th of Nisan. On the 11th she disappears; for three months she is not seen in the sky; on the 11th Duzu Venus is seen again in the West. Then there will be wars in the land, but the crops will flourish.'

These prognostications show us the Babylonian priest at work, with a list of the risings of Venus on different days of the month before him, and the corresponding events on earth written against them—the entire apparatus being used to allow him to forecast future events.

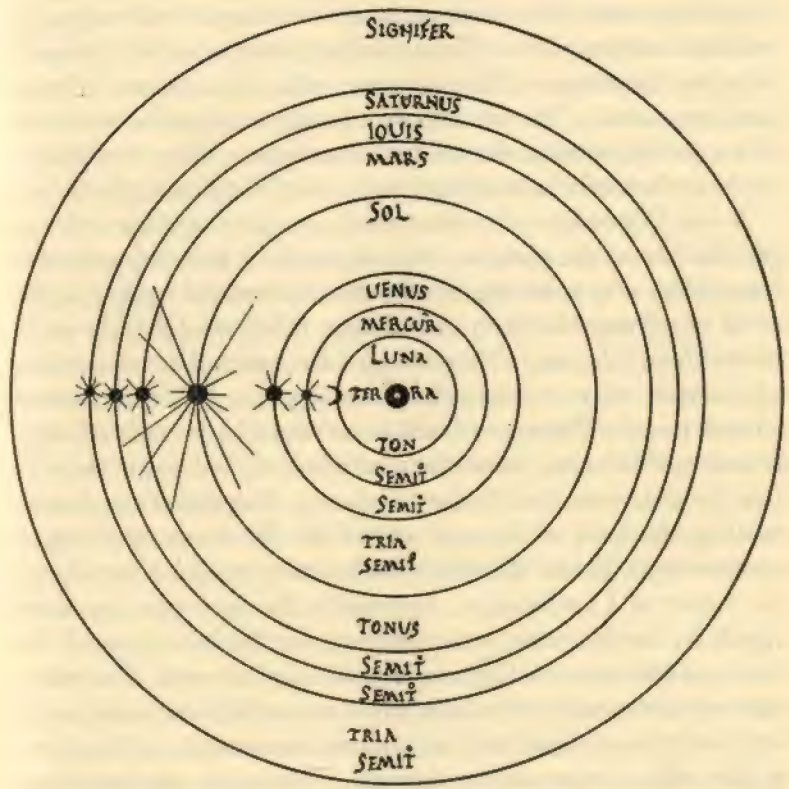


12. Ancient Mexican Sun God with Sun Disc, together with Morning Star, Moon and Hare

In Mesopotamia (Plate IV) and in Mexico (Fig. 12) Venus, the brilliant star of the morning and evening, was closely linked with the sun and the moon. As a morning star it would remind a lover to leave his girl before the day should break. Later, attention turned to Jupiter, Saturn and Mars and their course along the sky, their appearance and disappearance, were observed. Mercury, rarely seen because of its proximity to the sun, was studied last. The mysterious behaviour of the planets encouraged astronomers to continual endeavours. In appearance they revolve around the earth like the sun, the moon and the stars. But simple circular movements did not suffice to explain the strange way in which they advance and retire. Astronomers accordingly had recourse to the hypothesis that they moved in eccentric circles, the centre of the circle lying outside the earth. Others believed in epicycles whose

centre moved in a circular course around the earth. All these theories were summed up in A.D. 137 in Ptolemy's famous planetary system, which provides an ingenious mathematical account of all the movements of the planets. In formulating his theory he was compelled to assume that a number of epicycles existed for certain planets, as well as the existence of different points from which individual planets seem to move in a uniform manner: he was neither able nor willing to give up the idea that the planets had a circular and uniform movement like that of the stars. Moreover, he assumed that the earth lay motionless at the centre of the universe with the stars and constellations (including, as planets, the sun, the moon, Mercury, Venus, Mars, Jupiter and Saturn) moving around it. Their courses were related to each other in the same way as are the musical notes (Fig. 13). The Pythagoreans already believed that the movement of the stars caused a musical harmony in the skies and that the number and movement of the stars were connected with the different notes through a link of harmony.

According to Ptolemy the space between the earth and the stars was occupied by the seven planets, each of which described its course around the earth in such a way that these courses nowhere intersected, the distances between them being assumed to be wide enough to leave room for the epicycles. The effect of these epicycles was that the paths of the planets were elongated, a circumstance which, in the case of the moon and Mars, should have led to substantial variations in their magnitude. Ptolemy neglected this, as well as the attempts made by his predecessors to find different hypotheses to explain the movements of the planets. Hicetas of Syracuse assumed that the earth rotated around its axis; so did Heracleides, a disciple of Plato. Aristarchus of Samos went even further; he asserted that the sun and the stars were immovable and that the earth revolved around the sun, rotating around its axis once a day. Different views were held by Egyptian astronomers, who believed that Venus and Mercury revolved, not around the earth, but around the sun, and were carried by it



13. Ancient Diagram of the planetary orbits showing the corresponding notes

around the earth. The ancients failed, however, to synthesize these different theories into a comprehensive one to explain the movements of all the planets around the sun; nor were observations made to check the existing theories. The ideas mentioned were merely taken as eccentricities, like Hipparchus's idea of determining the position and magnitude of the stars, so as to allow later generations to discover whether any changes occurred in their rising and setting. His contemporaries merely regarded such proposals as blasphemous. The same charge was levelled against

Aristarchus and other modernists, whose ideas too violently contradicted current views. The orthodox theory was that the earth occupied the centre of the universe, with the stars and planets moving around it, the whole system being enmeshed in a network of reciprocal relations between stars and men. Who would dare to thrust the earth from its place and to rend the pleasing network?

It was Copernicus who succeeded in explaining those striking peculiarities of the planets—their regressions and their apparent immobility—by assuming that the sun, and not the earth, was the point of reference for their movements. It followed that the earth moved round the sun, which occupied the centre. The revolutions of the stars were explained by assuming that the earth rotated around its axis. These profound ideas could be formulated only because astronomers, particularly in Germany, had begun to question the correctness of Ptolemy's theory. The difficulties in calculating the dates of the new and of the full moon encouraged questionings. These difficulties had already caused comment at the Court of Charlemagne. Eventually the very peasants were struck by the inaccuracies in working out the behaviour of the moon, as Hermann the Lame reported about A.D. 1050. The calendar was out by only a few days; yet it was noted, and measures to improve it were taken; and this process continued until the Gregorian reforms were carried through. This at any rate was what happened among the Western nations, particularly in Germany, England, France and Italy. Elsewhere less importance was attached to a correct calendar and Ptolemy's theory survived. In the West, however, not only the calendar but the whole of the Ptolomaic theory and the entire theory of the sun and moon fell under suspicion. Viennese astronomers discovered that the epicycles postulated by Ptolemy would extend the courses followed by the planets to a degree which would be reflected in a striking change in their apparent size. In fact, however, no such alteration was observable. On the other hand, Nicholas Krebs, the famous Cardinal Nicholas Cusanus and Regiomontanus (alias Johannes Müller of Königsberg) had given thought to the earth's movement and its signi-

ficance. Special importance was attached to the position of the sun among the planets. In a popular handbook Georg Peuerbach explained this by saying that each planet had something in common in its motions with the sun and that the sun's course was, so to speak, the general mirror and natural law governing the motion of the planets. This was an important pointer to the sun's dominant position. Early astronomers, too, had described the sun as the lord and guide of the constellations, and as the source of heavenly light, comparing its position to that of the heart in a living organism. All this, however, was done in terms of astrology. It was reserved to Regiomontanus at the age of twenty to put the matter in astronomical terms when he declared that the three upper planets were attached to the sun by their epicyclical motion, while Venus was attached to the sun in another way, adding that the sun stood among the planets like a king in his kingdom or like a heart in a living body. We do not know how far Regiomontanus advanced his discoveries. He died at forty, and nothing is known about the work of his later years.

Copernicus perfected the preliminary work done by his predecessors. Eventually his theory, placing the sun at the centre with the planets moving around it (including the earth, which rotates while the moon revolves around the earth) gained acceptance and provided the foundation for modern astronomy. The correct shape of the course in which the planets move (viz. the ellipse) was discovered only by Brahe and Kepler. After their work had been completed planetary theory was perfected until eclipses could be predicted to a fraction of a second and the existence of the planet Neptune could be deduced solely from its effect upon the nearest planet.

• IV •

COMETS AND PORTENTS

FROM time to time portents appear in the skies and terrify the nations. Comets have at all times been among these. Seneca writes on this matter:

'While order rules in the universe we do not notice it. But once the order is disturbed and an unexpected light begins to shine, we gaze at it, point to it and ask about it. It is a human trait to admire the novel rather than the great. So it is with comets. If a rare and curiously-shaped fiery apparition is seen, everyone wants to know what it is; we forget all else, and concentrate attention on the new arrival, wondering whether it is matter for marvel or for fear. Then prophets of doom appear, telling the people that the new comet is a portent of disaster. Hence the anxiety to find out whether the apparition is merely a heavenly body, or a token of fate. Yet can there be a nobler or more useful study than that of searching into the nature of the stars and the constellations?'

Seneca then went on to mention the explanation given by Apollonius of Myndus and by Epigenes on the nature of comets, and urged the need for a catalogue of former comets to be examined for a possible periodicity in their appearance. But this suggestion was not taken up by the ancients. Comets continued to appear, challenging observation and reflection; yet it was not until the sixteenth century that astronomers proved by observation that comets do not belong to the aery envelope of the earth, but to the part of the sky lying above the moon's track. It was only Kepler's new planetary theory that allowed Halley to calculate the course of the comet known by his name, and to predict its reappearance.

In the nineteenth century a relationship was established between certain comets and the swarms of shooting stars; later it was discovered that some comets gradually disintegrate between the track of Mars and that of Jupiter.

Apart from the comets, there was also Sirius, the star of good fortune, and the wise men's star, with which we will deal later. There was also the miraculous star in the Whale (Mira Ceti) which was discovered by David Fabricius in 1596, and which was given this name because of its behaviour: first it was visible for a time, then it disappeared, then reappeared, and finally vanished. Such a star apparently had not been observed within human memory. Those who thought so had, however, forgotten an ancient report recorded by Pliny. Pliny writes as follows about Hipparchus's discovery:

'Hipparchus has found a new star and also a star which came into existence in his time. The motion of this star, by which it came to shine in the skies, led Hipparchus to wonder whether this might be a frequent occurrence and whether the stars we regard as fixed may not in fact be in motion. He therefore undertook a blasphemous work: he compiled a list of the stars and constellations for the benefit of posterity. Moreover, he devised instruments to determine the position and magnitude of individual stars. He did this to make it possible to determine whether these stars begin and cease to exist, and also whether they increase or decrease. He hoped that among his disciples there might be one to ascertain their growth.'

This passage shows that Hipparchus thought he could explain the events he observed in terms of motion. Another of his works shows that the star coming into existence at this time was Mira Ceti, while the star he described as new apparently showed its light south of the Whale.

These two phenomena led Hipparchus to observe the stars and to compile a stellar catalogue, thus anticipating Ptolemy.

Hipparchus flourished about 129 B.C., and seventeen hundred years passed before a new message reached men from the stars and caused them to act. When in 1572 a brilliant new luminary appeared it was Tycho Brahe who understood the message and wrote the first treatise on a star. He reached the conclusion that it was not astrological interpretation that mattered, and that what did matter was the compilation of reported facts and the proof that this gradually fading star did not belong to the solar but to the stellar system. Kepler followed a similar line when a new star appeared in 1604. These new stars and Mira Ceti opened a new and important chapter in astronomy—the study of the light changes of the variable stars, which in turn provided an instrument for studying the structure of the stellar system and of the stars generally.

• V •

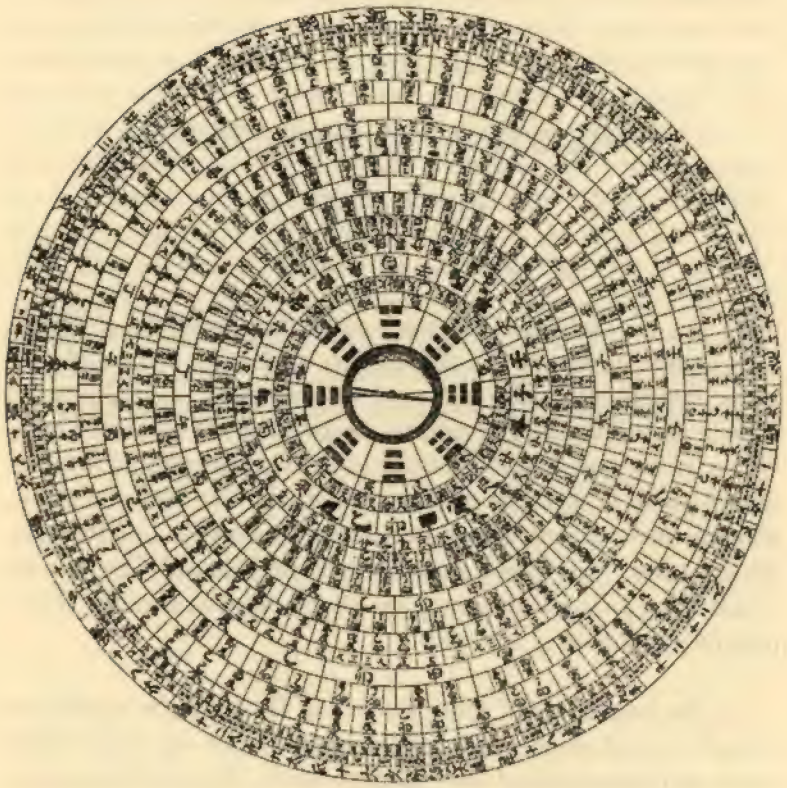
THE STARS AS MESSENGERS OF FATE

THE sun, the moon and the stars—these drew people's attention. Men began to observe the phenomena of the sky and sought to adapt themselves to the higher powers or gods. Temples were built in their honour. The process can be observed most clearly in China. In the appendix to the book of Yi-King (attributed to Confucius) there is mention of this adaptation: 'The heavens allow their pictures to hang down: they manifest good or bad fortune; the holy ones (the rulers) make them their pattern.' The way in which these pictures were supposed to be taken as patterns is explained in the *Book of Changes*:

'At the beginning of time, when Pao Hi ruled the world, he looked up and contemplated the pictures in the sky and looked down and contemplated the events on earth. He noted the markings of beasts and of birds and how they fit different environments. He began immediately by observing himself and outside objects. Thus he invented the eight signs to establish contact with the forces of the bright gods and to order the lives of all living beings.'

These eight signs (identical with the four main points of the compass and the four intermediate points) are shown on the Chinese magic discs called lo-king (Figs. 14 and 15).

The Chinese judged that plants could flourish only if farming activities were adapted to the course of the seasons. On this subject the book on 'Spring and Autumn' compiled from older works



14. Chinese Magic Disc, 'Lo-king'

by Lü Bu We in the third century B.C. contains the following passage:

'Mong Chun, the first month of Spring.

'In the first month of Spring the sun is in the sign of Ying Shi. At the time of dusk the constellation of Shen culminates. At the time of dawn the constellation of Vee culminates. Its days are Gia and I. Its divine ruler is Tai How. Its protective spirit is Gou Mang. Its beasts are the scaly beasts. Its note is Güo. Its key is Tai Tsu. Its number is 8. Its taste is acrid. Its smell is stuffy. Sacrifices

15. Diagram explaining a Chinese Magic Disc

are made to the spirits of the door. Among the sacrifices the spleen is the chief.

'The East Wind melts the ice. Animals awaken from their winter sleep. The fishes push their heads through the ice. The common otter sacrifices fishes. The migrating geese fly to the North.

'The Son of Heaven dwells in the Tsing Yang Hall, in the apartment on the left. He drives in the Coach of Pheasants, drawn by great blue-black dragon-horses. Green flags are hoisted. Men put on green clothes and wear green jade. People eat wheat and

mutton. Holes are bored in the sacrificial vessels to allow the air to pass through.

'On this day the beginning of Spring is celebrated. Three days before the Chief Astrologer proceeds to the Son of Heaven and speaks thus: "On such and such a day Spring begins; the vital force is based upon wood." Thereupon the Son of Heaven begins a fast. On the day when Spring begins the Son of Heaven in person proceeds to the Eastern Field, followed by the three chief officers, the nine high counsellors, the princes and the counsellors, to invite the Spring. Having returned, he confers decorations on the high counsellors, on the princes and the counsellors assembled in the palace yard.

'He instructs his ministers to extend kindness, to issue mild decrees, to spread happiness and to let the folk share in his mercy. Rewards and gifts are distributed according to people's deserts.

'He orders the Chief Astrologer to ensure that the laws are obeyed and to issue decrees, and to observe the course of the heavens, the sun, the moon, the stars and the constellations, so that the houses of the moon shall be determined without error in their regression, that the courses of the luminaries shall be calculated without error, and that the beginning of Spring is accurately determined.

'In this month on a propitious day the Son of Heaven prays to the Supreme Lord, begging that the crops may prosper. Thereupon a fortunate hour is chosen. At that time the King himself places a ploughshare at the third place of the car between a warden in armour and a charioteer. The Son of Heaven preceding the three chief officers, the nine high counsellors, the princes and counsellors, proceeds to plough the acre of the Lord. The son of Heaven ploughs three furrows. The three chief officers plough five furrows; the high counsellors, princes and counsellors plough nine furrows. Having returned to the Great Hall the Son of Heaven takes a goblet in the presence of the three chief officers, the nine high counsellors, the princes and counsellors, and addresses them thus: "This wine is the recompense for your trouble."

'In this month the influence of the heavens has descended towards the earth and the influence of the earth has ascended towards the heavens. Heaven and earth are in harmony, and unite their forces. The sap rises in herbs and trees.

'The King ordains the peasants' work. He instructs the supervisors to make their tents on the Eastern Field, to determine the borders and crossroads, to straighten the paths and drains, to make an exact survey over mountains and hills, valleys and ravines, plains and swamps, and to plant the five sorts of grain, each at the place where it will do best. They must be present everywhere so that the folk shall be instructed. If the fields are measured exactly in advance and the border lines are drawn, then the peasants know what they have to do.'

Eclipses

The case was similar with the other months; to observe the skies was among the astrologers' duties. More particularly they were charged with drawing the ruler's attention in good time to unusual phenomena like eclipses, and to cause the necessary measures to be taken. We can follow the procedure in the writings of Tso Ch'in-Ming, a disciple of Confucius, who wrote about the eclipse of August 14, 524 B.C.

'In the summer in the sixth month, on the day of Gia-Si, on the first day of the month, an eclipse of the sun occurred. The priest and the historiographer asked for the pieces of silk required for the sacrifice. Chao-Tse said: "When the sun is eclipsed the Emperor takes no complete meal; he causes the drum to be beaten by the altar of the earth, while the feudal lords offer pieces of silk and have the drums beaten in their courtyards. Thus it is prescribed." But Ping-Tse contradicted and said: "Not so. It is only in the first month before the evil influences make themselves felt that it is prescribed to beat the drums and to sacrifice pieces of silk if the sun is eclipsed. In other months it is otherwise." But the great historian

[Confucius] replied: "It is precisely for the sixth month that these procedures are ordained. After the sun has passed the Spring equinox and before it reaches the Summer solstice, if any mischance happens to the sun or the moon or the three celestial bodies, the mandarins lay aside their fine clothing and the ruler takes no complete meal and withdraws from his state apartments until the eclipse is over. The musicians beat the drums, the priest offers pieces of silk, and the historiographer delivers an address." '

More than two thousand years later similar practices continued in China, as is reported by the Jesuit Father, Louis le Comte, in 1686. This is what he writes:

'Some years ago certain respectable people who had read our books began to admit their error. But when an eclipse, especially one of the sun, occurs, the old practices are observed in Peking; these are sufficiently superstitious and laughable. While the observers (the Jesuits) are in the tower, engaged on determining the beginning and duration of the eclipse, the chief mandarins are on their knees in one of the halls or the courtyard of the palace, with their minds solely on what is happening in the sky. They prostrate themselves before the sun to show their sympathy, or before the dragon to pray that it may spare the world and not devour the luminary which it craves.

'For the rest, it is requisite that the mathematicians' forecast about the eclipse shall be fulfilled. If it were not to occur or were to be sensibly greater or less, or were to last a substantially longer or shorter time, the chief mathematician together with his colleagues would be in danger of losing their posts. But the mandarins charged with the observation set matters right. Whatever happens, everything is as it should be and—provided the officers have been bribed—complete conformity with the heavens is established.'

Another 250 years passed and this is what we learn from India:

VIII. *Figure for use of apothecaries*

IX. *Young man using the Ratisbon instrument for an observation*

X. *De Maupertuis declaring the flattening of the earth*

XI. *Married couple searching the sky for the planet Neptune*

'Today an eclipse of the sun is occurring in the Lahul mountains. For the last two hours the drums and trumpets have been roaring in the neighbouring monastery. The Lamas have put on their tall caps and are sitting in a circle, singing and praying, in the hope that the devil who is about to devour the sun will let it go. Now and then one of them jumps up and flings a glowing log in the direction of the sun. The village women are squatting in their houses, singing and wailing.' (*Frankfurter Zeitung*, March 9, 1936.)

Magic Discs

The fate of ordinary persons could be read from magic discs. These had a compass rose in the middle. Around it were concentric circles (Fig. 13), showing the Chinese elements, the points of the compass, the houses of the moon, the planets, and the twelve animals of the Far Eastern sequence. The employment of these discs will be discussed below (see page 70).

Discs of Fate

In the Mediterranean region the stars were interpreted under different forms. Bianchini's disc had the celestial North Pole at the centre. Around it ran the figures of the Far East animal sequence, the signs of the Zodiac, the Decan stars and the gods of the planets with their several regions within the Zodiac; this disc accordingly could be used for purposes of astrology in the Greek, the Egyptian or the Far Eastern style. Another sphere or disc of fate was that of Petosiris (Fig. 16). It was also known as the sphere of Pythagoras or of Apuleius, and was used to interrogate the future. In other words, the function of the disc was to discover the fate of a sick person, an escaped slave, or a fighter; it would tell whether the sick man would live or die, whether the escapee would return, whether the fighter would win or lose. We thus get a view of ancient life, where the future of a possible testator, an

A. III G. XV N XVIII T. XI
B. XXVII H. IIII O. III V. VII
C. XV I. XII P. XVIII X. VI
D. XXII K. VIIII Q. XV Y. II
E. XII L VI R XVIII Z. I
F. XXI M. III S VIIII

16. Sphere of Petosiris or Pythagoras, from a medieval manuscript

escaped slave or a wrestler was judged to be important. In the Middle Ages these discs were generally used to ask questions about life and death. The method was to use Roman figures which were written on the disc. Before this was done the name of the patient was expressed in figures; for this purpose a list of figures, each of which was supposed to denote a letter of the alphabet (the whole being inscribed along the edge of the sphere) was employed. To the resulting total the age of the moon at the day when the sickness commenced was added. If the total exceeded twenty-nine, then twenty-nine or a multiple of twenty-nine was subtracted. The remainder would then either fall above or below the horizontal line drawn on the disc. If the figure fell above the line, the patient would live; if below, he would die: life corresponded to the upper numbers, i.e. those above the horizon, and death to the lower ones, which belonged to the realm of shade. The whole was a foolish play with names and with the age of the moon, coupled with the old idea that life prevailed above the earth, and death below. The same was the case with the lucky and unlucky days in which the Egyptians believed, and with the kindred medieval ideas. Days were regarded as propitious or the reverse in accordance with the event—happy or unhappy—with which these days were associated in Egyptian theology.

Under What Star?

Horoscopes employing the constellation which happened to be rising were also derived from Egypt. If Hercules happened to be rising, for instance, this might be taken to denote that the person born at the time would be another Hercules or indeed an Orpheus, Prometheus, Theseus or Tantalus, a runner or dancer, a tormented or a weary man. Greater importance was attached to the rising of the signs of the Zodiac, each of which admitted several interpretations. Thus the Archer could signify either archery or else regal majesty (this was the Oriental view); or it could signify a great humane physician or a botanist or a tutor of

17. Triangles of the Signs of the Zodiac

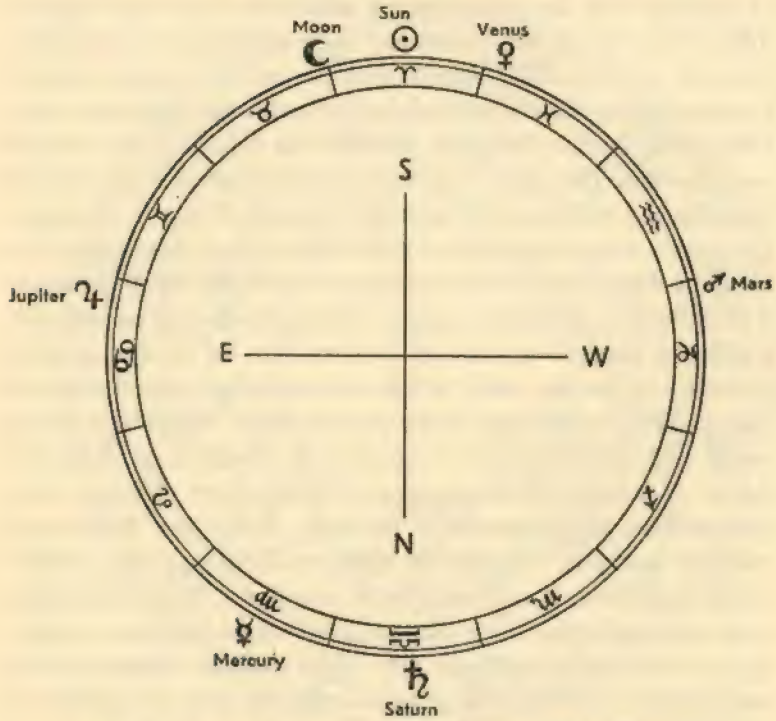
heroes or a wise prophet—these last-named being the Greek views. Furthermore, each sign of the Zodiac was subdivided into three equal parts (the Decanates); each of these being subordinated to a constellation or a planet. In this way the original influence of the constellation was weakened or strengthened. Another method

of dealing with the signs was to subdivide them into regions. These were of varying extent and were attributed to the planet (but not to the sun or moon). The size of the regions and the sequence of the planets depended on whether the Egyptian or the Babylonian or the Ptolemaic method was followed. But people went further. The signs were connected by means of equilateral triangles and were equated with the elements (Fig. 17). Or again, the planets were designated as rulers of the hour, dominating the hours of the day in a certain sequence. Eventually all the hours in a week were given distinct names. The result was that on each day a different planet was ruler of the first hour of the day, and by extension of the day itself, which was thereupon named after the planet. This is the origin of the present names of the days of the week. Out of this arose a special sort of astrology—that by means of which the horoscopes of newly-born children were derived from the properties of the ruler of the hour. If Mercury ruled the hour, for instance, the child would be an artist, a clock-maker or an astronomer, a teacher or a hedonist. Various qualities were also attributed to the planets. They could be warm or cold, dry or moist, male or female; they could connote different metals and different colours. The planets' influence thus left plenty of room for ambiguities.

In Egypt it was the rising of the planets, stars, constellations, Decan stars and signs of the Zodiac that were used for purposes of interpretation. A great variety of interpretations resulted. Eventually people gave up actually observing a planet; the planets were distributed over the hours of the week so that every hour had a planet as its ruler, regardless of whether the planet happened to rise or not in that hour. Here as in other parts of astrology, we find theory dominating and the facts being fitted to it.

Horoscopes for the Creation

Besides the horizon astrologers also considered what was going on among the stars above it. Chief of these events were the ec-

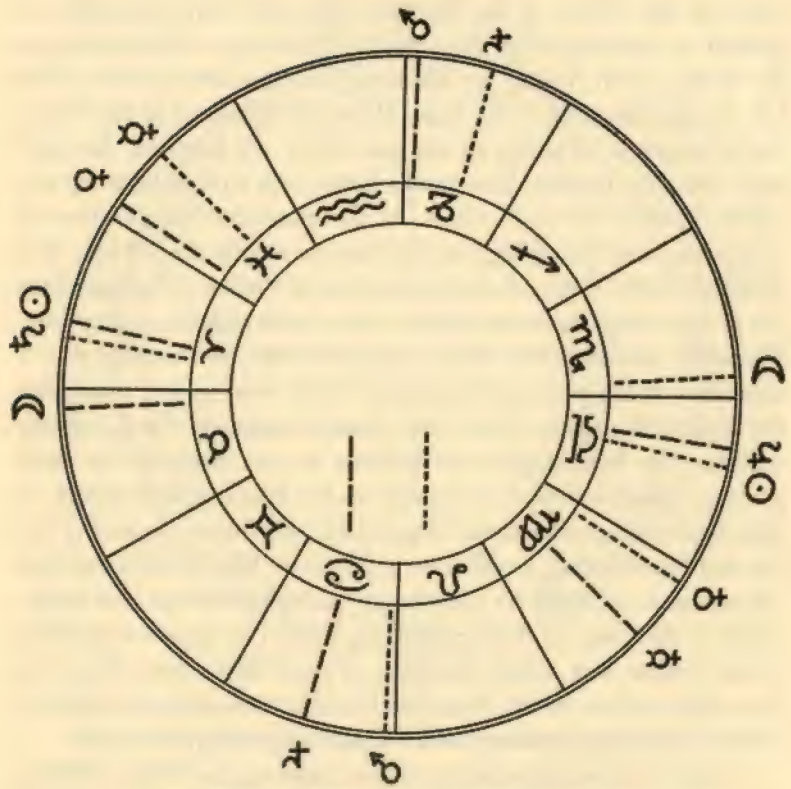


18. Babylonian Horoscope for the Creation of the World

lipses—sources of terror which compelled the priests to predict and observe them, giving timely advice of their coming to the King. The planets in their courses also demanded observation: they struck the imagination not only through their brightness and colour, but because they had been deified and were supposed to determine good and bad fortune through the positions they happened to occupy in the heavens. Their position relatively to each other, to the sun and moon and to the signs of the Zodiac were the relevant factors. Some of these positions go back to very old traditions and are connected with the horoscopes for the Creation, the 'Thema Mundi'. At the beginning of the first millennium B.C. the following positions of the planets which have been handed

down as the Places of the Mystery (Fig. 18) were probably regarded as propitious for the Creation: the sun is culminating in the South, with Venus on his right and the new moon on his left. Jupiter has risen in the East, Mars is about to set in the West, while Saturn is opposite to the sun below the horizon. Accordingly the sun, Jupiter, Saturn and Mars form a cross between the cardinal points on the horizon. At the same time the position of moon, sun and Venus high in the heavens recalls the old idea of a threefold deity. Only Mercury, standing to the left of Saturn, does not fit into the picture and seems to have been added at a later date. Probably this happened many centuries later; presumably this is also true of the precise indications which were given regarding the sign and degree where the planets stood at the Creation; whether the horoscope is propitious or not depends on their position relative to each other and to the four cardinal points. A Babylonian horoscope says: 'If a child is born when Jupiter is rising and Mars setting, it will have a fortunate life.' It followed that the position occupied by the planets in this horoscope was designated as the place of their exaltation, while the opposite position in the Zodiac was called the place of their depression (Fig. 19). Since the sun was in the Ram, the Creation was placed in Spring, which in the Babylonian system was the beginning of the year.

Another horoscope relating to the Creation, the Thema Mundi, is of more recent date; the Egyptian priest Petosiris was regarded as its author. The distribution of the planets in the Zodiac was as follows: The 15th degree of the Crab (together with the moon) is rising; then follow the sun in the 15th degree of the Lion, Mercury in the 15th degree of the Virgin, Venus in the 15th degree of the Balance, Mars in the 15th degree of the Scorpion, Jupiter in the 15th degree of the Archer, and Saturn in the 15th degree of the Goat, which is just about to set. The placing of the planets in the 15th degree of the respective signs was made in accordance with the normal Egyptian practice of placing the different points of the year at the 15th degree. Since the sun was in the Lion the point of time was one month after the Summer solstice (also after the early



19. Diagram of Exaltations and Depressions

rising of Sirius); the position is further confirmed by the rising of the 15th degree of the Crab, since Sirius as Decan star was, in the Egyptian view, ruler of the first third of the Crab. The horoscope is saying, in other words, that the planets rise in a series corresponding to their distances from the earth, and that this happens during the early rising of Sirius which marked the Egyptian New Year, a propitious date. This horoscope was used to attribute various qualities to the signs of the Zodiac. The series of signs from the Lion to the Goat was led by the sun and was described as the Day Houses of the Planets; the series from the Crab to the Water

Carrier running in the contrary direction was led by the moon and was described as the Night Houses of the Planets. In this way each planet was given its Day House and its Night House. The sun, however, was given only the Day House of the Lion, and the moon only the Night House of the Crab.

Neither horoscope can ever have corresponded with reality, since Mercury could never get as far from the sun as the horoscope assumed; the same applied to Venus in the Egyptian horoscope. The facts were distorted to establish a rule. The same had been done when the planets were made rulers of the hour.

The Flood and the World Conflagration

The Creation was supposed to be the work of the stars, and the same theory was held about its destruction by flood or fire. The Babylonian Berossos records an ancient Babylonian tradition which said that the world conflagration would be caused through the conjunction of all the planets in the sign of the Crab, and that the Flood would be caused through their conjunction in the Goat.

Theories were also advanced about the age of the world. Plato thought it was 10,000 years; Berossos made one world year equal 518,400 years. From the earliest rulers of Babylon to the Flood he reckoned 432,000 years, and thence to Alexander the Great, 36,000. The Indians used even bigger figures. They had an Iron Age of 360,000 years, a Bronze Age of 720,000 years, a Silver Age of 1,080,000 years and a Golden Age of 1,440,000 years. These periods, plus the appropriate dawns and twilights, gave a Great Age of 4,320,000 years. A thousand such ages made one World Day (Kalpa) of 4,320 million years, after which the World Conflagration occurred. Thereupon there were 100,000 years of uninterrupted rain, ending in the universal Flood. Life was renewed after Brahma had taken a night's rest lasting another 4,320 million years. Brahma's life lasted a hundred years of 360 days (each of which was equal to two World Days), i.e. 311 billion years, which equalled one Para.

The Toledo Letters

The Arabs continued the tradition of interpreting the conjunction of all the planets, or, alternatively, of the three upper planets, Saturn, Jupiter and Mars. This study first became known in the Christian West in the course of the twelfth century, through the Toledo Letters, so called after John of Toledo. In A.D. 1179 a prophecy was current in the East and West attributed to John of Toledo (also to Egyptian astrologers) which foretold tempests, earthquakes, famines and wars, for 1186, when a conjunction of the planets would occur in the Scales. A panic arose. The Archbishop of Canterbury ordered a three days' fast. But the disasters failed to occur and Gervase of Canterbury related ironically that the only tempests recorded in England at that time were those caused by the Archbishop's fulminations. And from the East we learn:

'According to the report of certain Eastern historians a great conjunction of the seven planets occurred, an exceedingly rare phenomenon. It occurred in the third degree of the Scales, a very airy sign if the rules of astrology be reliable. Every astrologer among the Muslim, including Anwari al-Hakim (otherwise known as the World Philosopher) foretold that tempests and hurricanes would arise in this year, destroying most of the houses in the country and causing the very mountains to shake. The people were sore afraid and prepared themselves subterranean vaults and shelters to escape this dread convulsion. Yet throughout the period designated by the astrologers no hurricane arose nor even any wind strong enough to prevent the peasants and threshers from stooking and threshing the crop.'

But though the prediction had failed (despite the fact that the planets were actually in conjunction in the autumn of 1186) and its failure had been followed by the inevitable jeers, the Toledo Letters continued to have periods of popularity. Yet it must have been clear to any astronomer that a conjunction of the comets in one sign must be a very rare occurrence after 1186. When such a

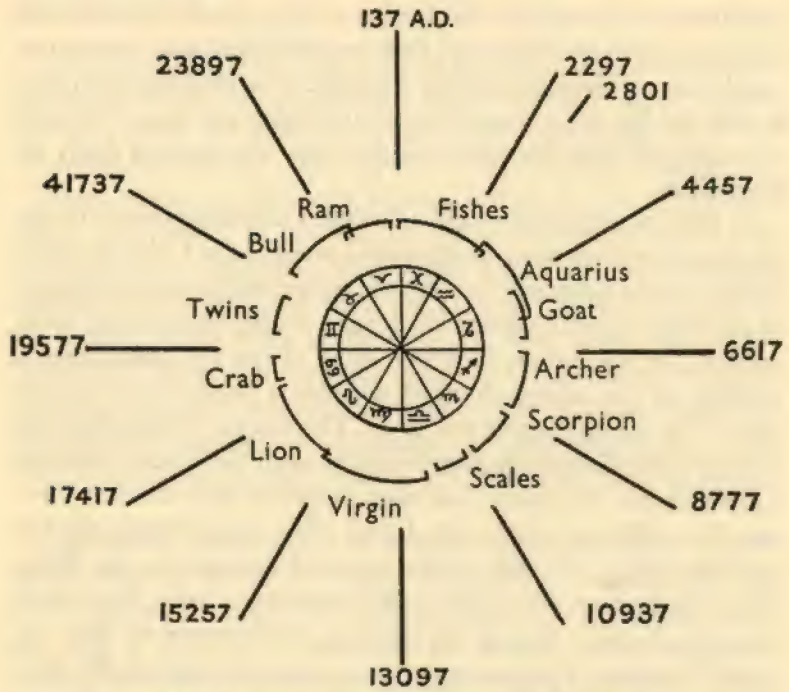
condition was foretold for September 9, 1371, the Flemish scholar and priest John de Wasia said that the calculation was wrong; the monk John of Meissen similarly discredited the prophecy for 1422, as also did the astronomer John of Gmunden for 1432. The one advantage of these forecasts was that they stimulated a study of the planets.

In the sixteenth century John Stöffler's calendar pointed to the number of conjunctions which would occur in the Fishes in 1524. This created a sensation; the almanac writers took the opportunity of pointing to the ill-effects which must result, chief among them a flood. On the whole, however, most of the 137 pamphleteers writing on the subject doubted whether a flood would in fact occur. Yet the excitement was great. The Elector of Brandenburg moved to the Kreuzberg near Berlin to await the Flood. Nothing happened; but the failure was soon forgotten and the next forecast, for 1586, met with ready belief. This was probably the last occasion when a Toledo Letter received credence in the West. Not so in the East, where this belief continues in force, if we are to trust the *Berliner Zeitung am Mittag*, which wrote on May 30, 1928: 'Numbers of people in Jerusalem spent last night in the open to await the end of the world which, according to forecasts, was to have begun yesterday with an earthquake.'

The Arabs built up a theory declaring that conjunctions of the planets had a special religious significance. Al-Kindi explained that a conjunction of Jupiter and Saturn in the Scorpion on March 29th or 30th, A.D. 571, caused the birth of the Prophet Mahomet, while the conjunction of Saturn and Mars in the Twins in A.D. 622 caused Mahomet's flight to Medina. In the Middle Ages the conjunction of Jupiter and Saturn, occurring every twenty years, was made responsible for a number of important events, like the Plague and the birth of Luther.

The Age of the Water Carrier

Recently a new method has been devised for causing alarm and despondency, namely to announce that the age of a given sign of



20. The Ages associated with the Signs of the Zodiac

the Zodiac is at hand. Thus, for example, the evil age of the Water Carrier is impending. What does this mean? The course of the sun and consequently the twelve signs of the Zodiac undergo a displacement within the celestial sphere, completing one full circle every 26,000 years. Hence in a period of 2,160 years the sign of the Ram, for example, has passed through the arc previously occupied by the Fishes and is about to enter the arc previously occupied by the Water Carrier. Figure 20 shows the position of the Zodiac and that of its signs as they were in A.D. 137 when Ptolemy observed them. The dates shown in the diagram indicate when the Ram will reach the place formerly occupied by the other signs. Thus in A.D. 2297 it will reach the position of the Water Carrier, in A.D. 4457 that of the Goat, etc. Outside the signs of the Zodiac

the corresponding constellations showing the arc they occupy have been drawn. It becomes clear from the diagram that there is a gap between some constellations, while others overlap. If we wanted to wait until the Ram (or the beginning of Spring) reached the frontier of the Water Carrier, we would have to wait until A.D. 2801. We therefore have plenty of time; moreover, we can choose whether to wait until A.D. 2297 or until A.D. 2801 before the good or the evil days of the age of the Water Carrier begin.

The Fiery Comets

What of the fiery symbols in the sky? At all times comets (Plate VI) have been causes of terror. They were supposed to be harbingers of important events, like the birth and death of princes. For instance, two great comets, visible for a period of seventy days and occupying a full quarter of the sky, were supposed to have given warning of the birth and later of the accession of Mithridates Eupator. These events are supposed to have taken place in 132 and 120 B.C. Evidently these stories reflect the fear inspired in Rome by Mithridates: in fact, no major comet was visible in those years. The story that those comets were visible for seventy days was invented to establish a sort of parallel with the age of Mithridates—sixty-nine years. Much the same is the case with the comet appearing on a commemorative coin for Julius Caesar. The comet appeared in the autumn of 44 B.C., six months after Caesar's death, and could not therefore have foretold his assassination. Later, in 17 B.C., when a light with a long tail appeared at night, people thought that the comet had returned. To commemorate this the coin showing the head of a youthful Caesar, together with the comet, and the inscription DIVVS IVLIVS was struck (Plate V). Later, Augustus caused coins to be minted bearing his portrait and the same lucky comet of the Julii.

Great popularity was enjoyed by pamphlets dealing with the seven or nine distinct species of comets whose appearance, course and tail permitted various interpretations. At last, in the sixteenth

century, the distance of comets from the earth and the direction of their tail relatively to the sun began to be examined. This meant the beginning of modern studies. Yet even in the seventeenth century comets were described as being the work of evil spirits, and their influence has been regarded with fear until today.

Major comets, like Halley's, have always spread panic. They were looked upon as harbingers of disasters like the destruction of Jerusalem in A.D. 70, the defeat of Attila on the Catalaunian Plains in A.D. 451, and the Norman Conquest in 1066. These feelings are attested in ancient works. An intaglio exists, probably representing Halley's Comet in 11 B.C. (or A.D. 218), the comet being represented in each case alongside a lion's head (Plate V). On its return in 1066 the comet was given a place in the Bayeux Tapestry. Even at its latest appearance in 1910 the comet caused disquiet; on May 19 the earth was supposed to pass through its tail. In some places, e.g. the Philippines, anxiety grew to such a pitch that P. G. Zwack wrote a pamphlet to calm perturbed spirits. Elsewhere people showed greater calm. When Camille Flammarion was reported to have foretold the end of the world for May 18, the *Roland von Berlin* published the following poem, ironically commenting on the spirit of the time:

'Wretched men, learn
What is written in the Book of Fate.
The frightful comet is approaching,
Wagging its monstrous tail.

'But don't let's be frightened.
Let's enjoy life;
Chaps, life will only be beginning
When we all disappear.

'Flames will flicker in the East
When the world drops into its grave.
Then the last policeman
Will move off to his station.

'Because in a case like this
Even the authorities are at a loss.
Chaps, life will only be beginning
When we all disappear.'

Less important comets also troubled people in the nineteenth century. Mädler writes in virtuous sorrow: 'Who would have thought that in this year of 1857 an obscurantist would have succeeded in causing a panic among millions, not among the semi-barbarous South Sea Islanders, but in countries boasting to be at the head of civilisation—and this without the very slightest cause, real or imaginary.'

However, this comet of 1857 (it was discovered by d'Arrest) had one virtue. It provided an occasion for De Coster's amusing petition as well as Sickert's pretty Munich cut-out sheet showing the collision between the earth and the comet. We are also indebted to the comet for Daumier's brilliant picture on the contemporary fears (Plate VI, 2).

War in the Heavens

Fiery globes were also noted and were occasionally pressed into the service of astrology. The Sibylline Oracle, which was produced about the beginning of our era, contains an episode dealing with the war of the stars—a description probably based on Babylonian influences, dealing with the appearance of two great fiery globes, as big as the sun and the moon, and their effect on the stars, ending in a battle of the stars and a final world conflagration.

'I saw a burning sun among the stars threatening,
I saw the moon's wrath in lightning,
The stars were pregnant with battle. God let them fight.
Long flames shot athwart each other in place of the Sun.
The Morning Star directed the battle mounting the lion's back,

The Moon's two-horned sign of mourning changed.
The Goat thrust back the young Bull's neck.
The Bull in turn robbed the Goat of the day of homecoming.
The Balance displaced Orion
And its place knew it not.
The Virgin in the Ram took over the lot of the Twins.
The Pleiades ceased to shine.
The Dragon denied the Girdle.
The Fishes took shelter over against the Lion's girdle.
The Crab yielded its place, for it feared Orion.
The Scorpion attacked the tail of the dread Lion.
The Dog slipped down by reason of the Sun's flame.
The Water Carrier set fire to the might of the strong Shiner (Saturn?)
Uranus rose in his might until he caused the fighters to tremble,
Flinging them down to earth in his wrath.
Thus they were hurled down to the baths of ocean,
Setting fire to the whole land. The whole ether was without stars.'

The Terror of the Meteors

The big stone which dropped from the sky near Strasbourg on November 7, 1492, caused a panic. Sebastian Brant wrote an account of it which was so popular that it was reproduced in four separate pamphlets. This is the first printed notice of a meteorite. The stone was hung up in the church at Ensisheim. But earlier records exist. In Mecca a meteorite was worshipped in the form of the Ka'ba and in China (at Ling-Shi) one was the object of worship in the Court of a pretty little temple.

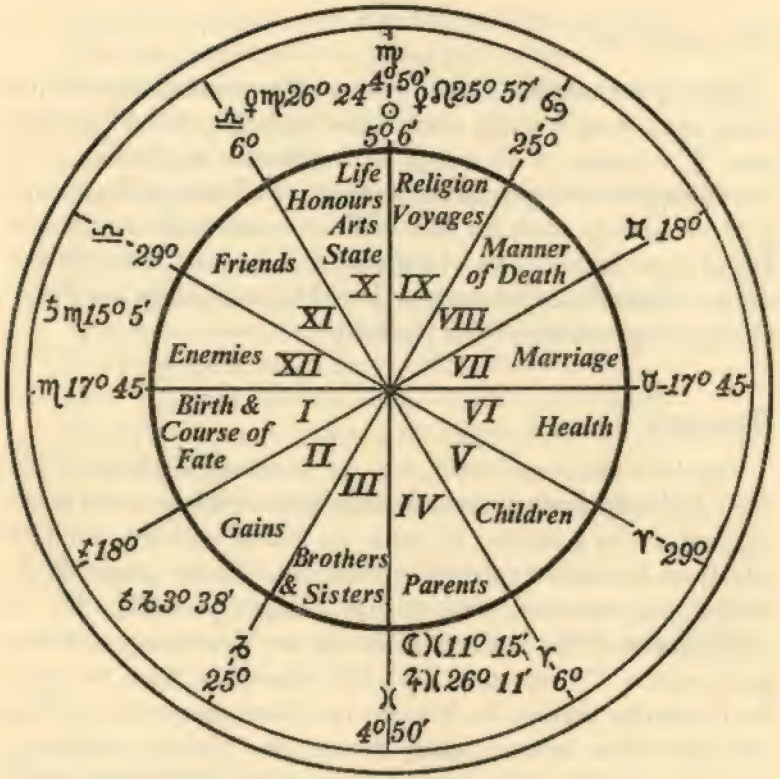
In October 1933 a heavy fall of shooting stars lit up the skies, causing panic in Portugal and elsewhere. Women screamed and ran for shelter to the churches.

The Lucky Star

Among the ancients Sirius was usually considered to be the lucky star; its early rising marked the beginning of the Egyptian year. The nature of its rising, its brightness or dimness were details supposed to govern the coming year. Sirius as Decan star is also a tutelary spirit for men while it is above the horizon; in Egypt in particular it was widely held that the stars were tutelary spirits. A person's lucky star was that which was rising (and therefore entering into activity) at his birth.

Horoscopes

Regularly recurrent events, e.g. the seasons, the phases of the moon and eclipses were normally shown in calendars for the coming year, or for a number of years. An individual's fate could be told from Petosiris's sphere, or from the Chinese magic discs. Horoscopes, however, came to play a bigger part (Fig. 21). A configuration of the heavens exists for any given time and any given region. To represent the forces emanating from the stars the horoscope divides the heavens into four quarters as well as into the twelve houses, which denote life, business, brothers, father, sons, health, wife, death, religion, reign, good deeds, gaol. The continuing changes in the relative positions of the signs and planets is done justice to in the following way. The four quarters and the houses are inscribed on a central disc, around which another disc is imagined as rotating, showing the twelve signs of the Zodiac and the planets. The positions of the planets could be looked up in the calendars or else could be worked out for the occasion, though this took time and trouble. The really essential question, however, was how to project the circle bearing the signs of the Zodiac (which is at an angle to the horizon) on to the horizon. From the earliest times three methods existed, each showing different limits to the houses inside the signs which were then entered into the horoscope. Moreover, in interpreting the posi-



21. Goethe's Horoscope

tion of the planets and in evaluating the properties of the signs, and again in subdividing them, there was room for different opinions; so that any interpretation was very much a matter of the astrologer's choice.

Most horoscopes were cast to foretell a person's fate. The start was frequently made from the moment of conception and not of birth, as Ptolemy had suggested. Horoscopes were also cast for founding towns and universities, for religious movements, for comets, and parhelions.

Star Mates

Wandering scholars did not trouble themselves with the details of a horoscope. What struck them as more important was that the help of the stars could be used to promote a special friendship with a pretty girl. One of the medieval Carmina Burana says on this subject:

> 'When Mercury and Jupiter
> Saluted each other in the Twins;
> When Mars and Venus
> Were kissing in the Scales—
> My little Cecily entered this world—
> The Bull was at its setting.
> Exactly the same conjunction
> Has been found to be mine.
> Thus by the grace of the Hours
> I have been made her mate.
> Through my stars
> I am joined to her star.'

· VI ·

ASTROLOGY AS A GAINFUL OCCUPATION

ORIGINALLY the interpretation of what was going on in the skies was the monopoly of priests and astronomers. It was their business to work out when any of the regular occurrences was likely to take place, and to advise the ruler, who could then avert threatening evil by fasting. The priests were also charged with the calculations necessary for the calendar. In China the office of Court Astronomer survived until the eighteenth century. Apart from these people there were astrologers who foretold a person's future by collating the time of his birth with the magic disc. Marco Polo has left the following report on the work of astrologers whose activities he studied in China from 1271 to 1295:

'When a person of quality dies and the body is to be burned his relatives assemble the astrologers and acquaint them with the year, day and hour on which the deceased person was born. The astrologers then consult the magic disc. Having determined the constellation or sign and the planets ruling in it, they thereupon indicate the proper day for the funeral. Should it happen that the same planet is not then in the ascendant, they give instructions for the body to be preserved for a week or more and sometimes for as long as six months.'

In his novel *Kin Ping Meh*, the writer Wan Shi Chong (1526–1593) gives the following account of how astrologers worked: 'Starting from the four astronomical double signs relating to the hour, the day, the month and the year, the astrologer worked out an unpropitious position for the star of their marriage.' And again: 'And indeed they soon reached an open booth lined with blue

cloth where a magician learned in the calendar sat and waited for a chance to give the passers-by for a small fee prognostications and information about the calendar.'

Consultation of the magic disc has remained popular until this day.

In Egypt Petosiris was a famous priest and astrologer. It is established that he flourished in the fourth century B.C., when Alexander the Great conquered Egypt. At that time he was a priest of the God Thot at Hermopolis. In the third century his tomb was commonly visited by Greeks who venerated him as a great sage. We saw above that he was supposed to be the author of the sphere and the Thema Mundi. The astrologer and snake-charmer Hor-Kheb was a contemporary of his; his statue (lacking head and feet) has been discovered in Egypt. The inscription on this figure is characteristic and worth quoting:

'The prince and viceroy and incomparable friend, skilled in the sciences and observer of all the natural processes in the heavens and on earth, expert in observing the stars without neglecting half of them, casts a horoscope based on the position of the stars and of the gods who determine the future. He knows about them and their days and about the influence of Venus on the earth; he is thus enabled to make happy the nations by his prophecies. He observes the culminations and emersions and announces the coming of each festival at its proper date. He foretells the appearance of Sirius at the beginning of the year, and observes the day of its festival; he has calculated its coming at the due season and observes its daily course; accordingly he knows its law. Thanks to his knowledge of the rising and setting of the sun and of the measure of its changes he uses it to tell the hour of the day, publishing its due appearance and its hourly changes while it is invisible. The movement of the star of Horus in the sky. . . . Instructed in all matters of the lord he applies to the earth what he has observed in the skies. In knowledge of its breathing. . . . None contradicts his decisions once he has decided a matter in the light of his observations. No master

can alter his advice in the eyes of the lord of the two lands. He tames the scorpions, he knows where all creeping things hide; he points to their hiding places and draws the serpents from them; he closes the jaws of their inhabitants. Their serpents . . . initiated into his secrets, they favour his journeys and protect his path by plaguing the (opponents) of his undertaking. . . . They congratulate themselves on his advice. God makes his favourite the master of the scorpion, Hor-Kheb, the servant of the servant (of the lion-headed goddess) at Uazit.'

We have thus become acquainted with the Egyptian astrologers and their advertisements. What did their clients want to know? Petosiris' sphere was used when people wanted to know how an illness or a fight would end, or whether a runaway would be caught. Greater importance was attached to what would become of a child. Answers were given in the books of the Egyptian god of wisdom, Hermes Trismegistos. According to whether a certain part of one of the signs of the Zodiac was rising, or a planet was at a certain position in the Zodiac, a child might become any of the following: King, prison governor, gardener, bricklayer, stonemason, tailor, voluptuary, pimp, shepherd or a foolish and cowardly scandalmonger. He might be shameless, he might become a groom, a donkey-driver, a man of business, treasurer, entrepreneur, peasant or viceroy; he might be a servant, impudent and changing masters for his own benefit; a malefactor, or libertine, though fond of music; a famous doctor, notary, botanist, prophet, priest, a wealthy citizen, a schoolmaster or mathematician, a town clerk, a precentor or a surveyor. Astrologers also occur; they sit around and accost people. Astronomers are judged to be inventors of divine things (theoreticians?). On one occasion pious astronomers and astrologers, 'with their hopes constantly directed towards God', are mentioned. If the sun is in the house of Mercury the child is likely to become 'learned in the stars but making a poor living in the service of science and knowledge'. The astronomers of the time may have looked fondly back to the old days when it

was written: 'The learned man's belly is filled by reason of his learning.'

From Egypt and from Mesopotamia astrology travelled to Greece and thence to Rome, the capital of the Empire. It soon became popular among the élite, though from time to time astrologers were expelled and rhetoricians like Cicero could point out their blunders in passages like this: 'To my certain knowledge the Chaldeans told Pompey, Crassus and even Caesar that they would reach a peaceful and glorious old age. And so I am surprised to find credence being given to such people whose prophecies are daily contradicted by the event.' At a later date Juvenal wrote:

'No mathematician is believed to be worth anything unless he has first been in trouble with the police. But say he has just managed to escape a capital sentence, or was allowed by special clemency to return from the Cyclades or from the rocky island of Seriphus: then your wife will consult him about why your jaundiced mother is such a long time in dying or when your turn will come or that of her sisters and uncles. . . . Avoid specially those women who carry about a dog-eared calendar, who no longer consult but are consulted, and do not follow their husbands in their campaigns because Thrasyllos' calendar tells them not to. If she is going to drive a mile she looks in her book for the most propitious hours. If her eye itches she looks through her horoscope for the best medicine. If she is lying ill in bed the best time for eating is that which Petosiris prescribes.'

Let us now take a look at Asia Minor. In Gorgani's poem 'Dis and Ramin' (eleventh century) we read:

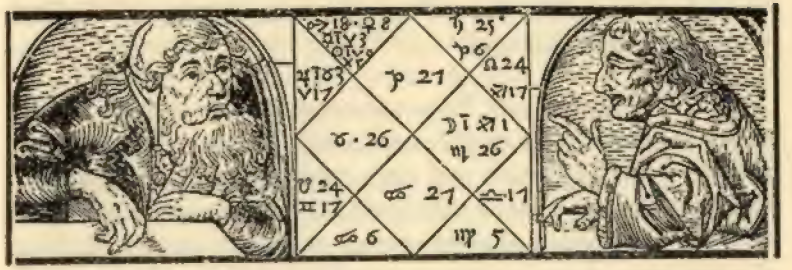
'Astrologers came from every city,
The elect of Khorosan with wisdom on their lips.
One would say, "The moon in the Ram has caused this,"
Another would say; "This happened by virtue of Saturn in the Crab." '

Here is an instructive passage on the position of astrologers in India (sixth century A.D.):

'An astrologer should be of good family, of agreeable appearance, well-built, of fair size and with shapely limbs. He should not be disfigured by any blemish; his hands, feet, nails, eyes, teeth, ears, eyebrows, forehead and chin must be well-formed and agreeable. He must have a good figure; his voice should be light, clear and euphonious. In short, he should be a man of presence, for as a rule there is a connection between a man's good and bad inward qualities and his outward appearance.'

Moreover, we learn that an astrologer should possess sound morals, truthfulness, magnanimity, promptness, knowledge, intelligence, mild manners and goodness. He must be neither excitable nor malicious; his knowledge should be superior to that of his fellow students, so that the success with which he practises shall enhance the glory of science. Besides all this he must be free of vices, he must know the expiatory sacrifices, be a master of medicine and white magic; he must be devout and pious, he must fast and practise austerity. His mind should be above the ordinary, so that he can supply the right answer to any question, saving only those cases where supernatural forces limit his knowledge. Finally, he must be very learned in the knowledge of the stars, of horoscopes and of the constellations.

This was the time when Christianity was spreading in Europe. Its fight against astrology will be mentioned below. After the fifteenth century scholars of standing were frequently asked for horoscopes (Fig. 22) and for glimpses into the future. The way they handled these tasks can be seen from the following examples. In 1451 Regiomontanus on the instructions of the Emperor Frederick III cast the horoscope of his fiancée, Leonora of Portugal. Later, after giving birth (March 22nd, 1459) to her son Maximilian, who later became the Emperor Maximilian I, she asked



22. A Horoscope with its Interpreters

Regiomontanus to read the boy's future from the stars. Regiomontanus complied in the following terms:

'It is a heavy burden that you, most mighty Empress, have placed upon my shoulders, in asking me to foretell your son's future from the stars; it is a hard matter, and one of the greatest difficulty to read from them a precise message about the future. Who would undertake this must know many matters. For who shall rightly evaluate the nature of the stars and their varying influences unless he possesses a complete knowledge of science and philosophy? No doctor can foretell with certainty how illness will end unless he possesses a long experience; how much more are long and profound studies needed if the stars are to be correctly interpreted?

'When I began my labours a great fear descended on me. Nature has endowed me with certain gifts; yet I am well aware that I do not possess the requisite information. None the less I must obey my great Empress's instructions. Yet if it should prove that I have discharged my task but imperfectly, then I hold some blame must go to her who gave the order as well as to him who executed it. I will undertake this heavy task the more readily since I may fairly assume that you possess such knowledge of these matters and will therefore be indulgent, since the standard which you set is so exacting. I do not doubt that, as with other matters,

so with my forecast, you will use the understanding with which you are so richly endowed.'

In the ensuing years Regiomontanus began to have doubts about the correctness of his prophecies. He said as much openly in letters written in 1465 and 1471, when he said that he did not wish to waste his time on astrological forecasts, though he would have further opportunities of writing on this subject. He spoke of the elements of uncertainty in astrology, mentioned the contradictions among astrologers as well as their self-contradictions, and added that he would shortly be publishing a work on this subject. He was prevented from doing this; he travelled to Rome in 1475 and died there in the following year.

With Regiomontanus the modern study of astronomy began. Astrology lost esteem. In a letter dated 1587 Tycho Brahe wrote:

'I cannot withhold from you my view that I dislike spending my time on astrology and prophecies; these are worthless occupations. My taste is for astronomy, which studies the curious courses of the luminaries. For some years now I have been trying to introduce order here.... Each year, however, I provide an astrological forecast for my master the King, whose wishes I must comply with, though personally I regard such matters as trivial and dislike such dubious prophecies. This is not the way to the truth. The true way is found in geometry and arithmetic; these, together with a studious observation of the heavens, are the basis of astronomy.'

Kepler (1571–1630) followed much the same development as Regiomontanus. At first he enjoyed publishing successful forecasts in his calendars. Later he began to have doubts. As early as 1606 he wrote to Thomas Harriot in London:

'I hear you have had trouble over astrology. What I ask you is this —is astrology worth such trouble? Ten years ago I refused to have anything to do with the division of the skies into twelve

equal parts, houses, patronages, planetary trines, etc.; I have merely retained the aspects, and I am establishing a connection between astrology and the theory of harmonies.'

We are indebted to Kepler for considerable work in the field of astrological interpretation; his fame was founded on a number of prophecies contained in his calendars. Yet his horoscopes were far from infallible. In January 1598, his own son Henry and Mästlin's son Augustus were born. In a letter to Mästlin dated March 15, 1598, Kepler discussed the two boys' future. He said that young Augustus would be in no danger of dying in the coming years, though it would be necessary to be careful next December, when epilepsy would be threatening. There would be no threat to his own child until 1601. Yet both the children died in April 1598.

Greater importance attaches to the horoscope which Kepler cast in 1608 for Wallenstein. It was cast with careful observation of all the rules, and foretold that Wallenstein would die in his seventieth year of a quaternian fever or a stroke unless, indeed, he should have died in his twenty-eighth or his fortieth year. These prophecies simply did not agree with the facts of Wallenstein's life; no more did the prophecy relating to his future illnesses or that which foretold that he would marry in his thirty-third year (1618), whereas in fact he married in 1609 and again in 1623. All this prompted Wallenstein to add manuscript notes on important events in his life to the horoscope and to return it to Kepler with a request for amendments. Such amendments were nothing unusual: it was customary to excuse the need for them by declaring that the statements previously provided about the hour of birth had been vague and had made it impossible to ascertain the exact position in the skies and hence to make a precise forecast. In order to get more exact data about the moment of birth astrologers commonly began from important moments in the person's life (e.g. severe illnesses) and asked by how much the hour of birth reported to them had to be altered in order to obtain agreement between the events and the forecast. In the case of important per-

sons substantial adjustments were not uncommon. Thus the date of Luther's birth (November 10th, 1483) was moved to October 2nd, 1484, in order to get the right position of the planets needed for a future great reformer. In the case of Wallenstein all Kepler had to do was to change the time of birth by half an hour in order to get a better agreement between the forecast and the facts. He thereupon worked out Wallenstein's future life and sent a new horoscope in January 1625. In doing this he was as well placed as an astrologer can be; he knew the person for whom he was casting the horoscope, he knew his past career, and he knew what sort of circumstances might be of importance for an eminent soldier. His task obviously was to point to every unfavourable position which the planets might take up so that Wallenstein might take note of these influences. Did Kepler's amended horoscope prove sound? Clearly not, if we compare his forecast with Wallenstein's later annotation and with the facts. Kepler regarded 1627 as a dangerous year; in fact it was the year when Wallenstein won his victories over the King of Denmark. Wallenstein's relegation in August 1630 and his reinstitution in December 1631 were unknown to the stars. The period from 1632 to 1634 was propitious according to the horoscope, save only for the opposition of Jupiter and Saturn in March 1634. Yet what happened? On February 25th, 1634, Wallenstein was assassinated at Eger. Once again the stars had failed. Kepler did not live to see this manifest miscalculation; but there were plenty of other horoscopes to tell him how frequent such failures were. He carefully compared his life with the forecasts and found that his own brilliant career was not written in the stars. Moreover, he was well aware that the current views regarding the infallibility of horoscopes was wrong: 'Where a horoscope happens to be correct,' he wrote, 'people remember it. Failures are forgotten: there is nothing out of the way in a failure. And so the astrologer is not without honour.'

This was the time when the old classical astronomy broke down. Astrology entered into a decline. The common view was summarised by Tobias Beutel in 1668, in his *Arboretum Mathematicum*: 'We know by experience that there are many instances when astrologers made correct forecasts; but there have been hundreds upon hundreds of failures. On the whole we should not trust horoscopes and no Christian man should fear or hope by reason of what his horoscope tells him.'

The general confusion caused by the two World Wars provided a powerful stimulus to this sort of abuse. The *Daily Mail* wrote in 1916:

'One effect of the war has been to breed clairvoyants in every quarter of the country. Crystal gazers, palmists, and those who profess to be able to fathom the future by means of a mysterious knowledge of the sun, stars, coloured globes and packs of playing cards are prospering as never they have done before, mainly at the expense of the wives and sweethearts of soldiers.

'In the West End of London a common charge by those who have a tariff is £1. 1. for palmistry and £2. 2. for clairvoyance. One woman prosecuted recently at Westminster was stated to have been booked five weeks in advance to peep into the future. . . . In the London suburbs and the provincial towns half a crown or five shillings is the usual charge . . . with palmistry at the war-time price of 1s.'

Things were just the same in Germany; here, too, astrology flourished, particularly in the South, where calendars, prophecies and every kind of astrology had always been popular. It goes without saying that the popularity of these abuses meant good business (Plate VII). In 1916 people had to pay twenty or thirty Marks for a horoscope; later the price rose. In 1948 the *Neue Zeitung* (No. 117) reported: ' "The full moon was shining into the room and was playing on your chubby cheeks. By your side lay your mother, weak and exhausted; her pale features showed a happy smile." This was the standard beginning of each of the thousand horoscopes which the astrologer F.M. (22 years) of Hamelin sold for 60 Marks each. He has now been sentenced to three months' imprisonment for fraud.'

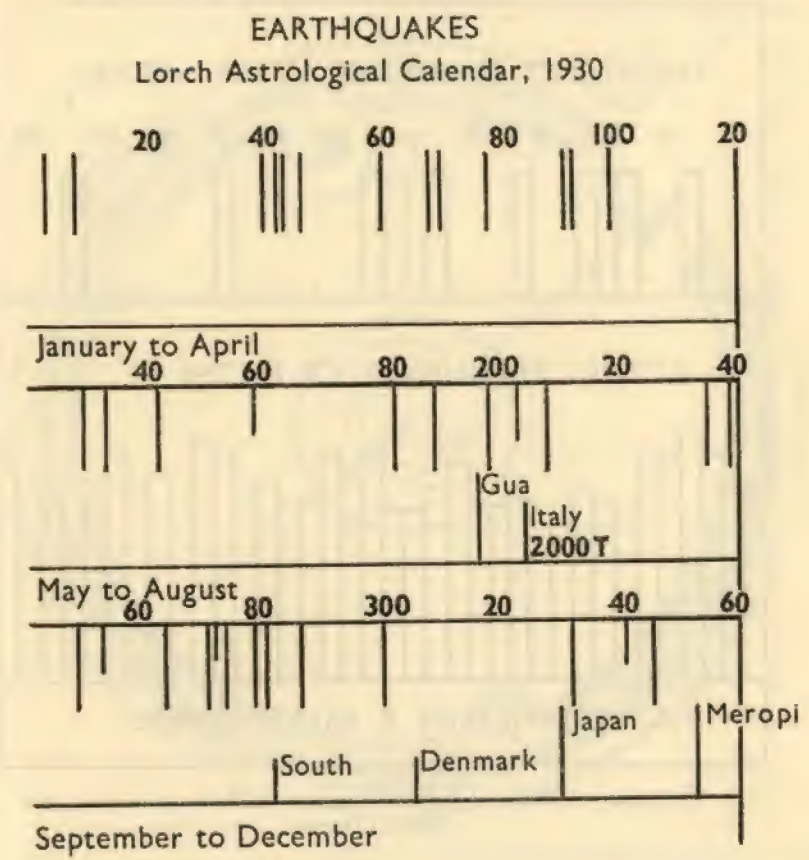
• VII •

ASTROLOGERS WITHOUT IMAGINATION

A THOUSAND years of studying the stars had caused astronomy to make substantial progress, while astrology was eventually proved to be guesswork. For centuries a number of assumptions were accepted as true; the moon was supposed to affect the weather, the eclipses and comets were believed to foretell disasters. All this was eventually shown to be meaningless or incorrect. Moreover, certain astronomers who (like Regiomontanus, Brahe and Kepler) also practised astrology and the casting of horoscopes, contributed their own experience. It might have been thought that these men, who could calculate the course of the planets as well as being masters of astrology, would produce a maximum number of accurate forecasts, particularly regarding the length of their clients' lives, since a correct answer was a matter of first importance for their princely patrons. But if their forecasts are examined the number of hits will be found to have been small.

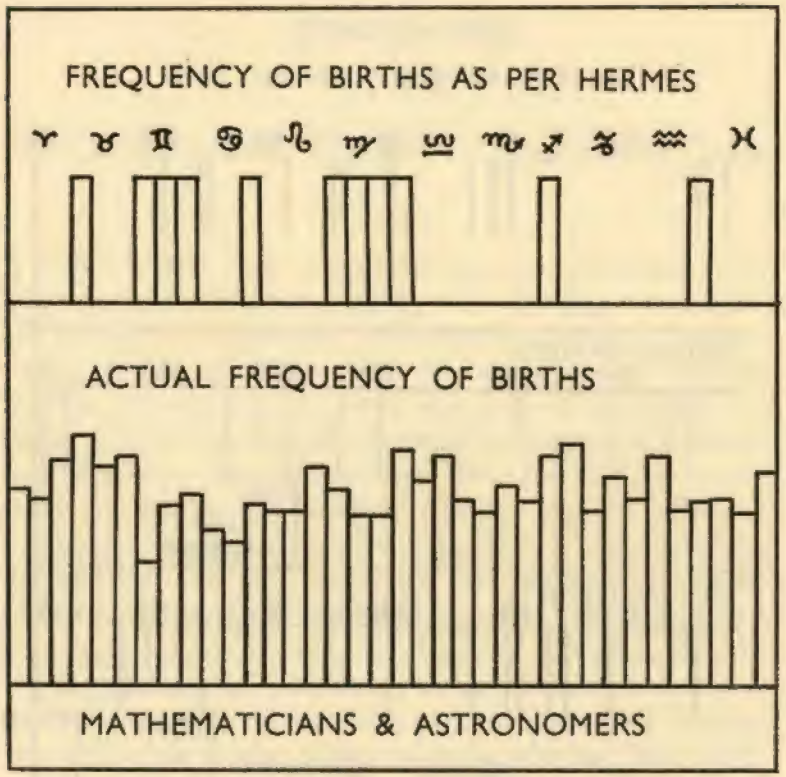
Despite these failures astrology and other forms of fortune-telling have experienced a revival. A fair number of calendars exist foretelling disasters for certain days. Evidently nobody takes the trouble to check the accuracy of these forecasts. If checking were commoner, the earthquakes for instance forecast in the *Lorch Astrological Calendar* for 1930 would be found to differ from the facts as widely as those given in Fig. 23, which shows that numbers of severe earthquakes causing many deaths were not forecast in the calendars. The case was similar with aeroplane and mine disasters. Moreover, the excuse valid in ancient and medieval times that the movements of the planets were not known with sufficient accuracy, can today no longer be accepted.

Much the same is the case with horoscopes based on the date of



23. Deaths caused by Earthquakes in 1930, as foretold astrologically (Downward Lines) and as actually occurring (Upward Lines)

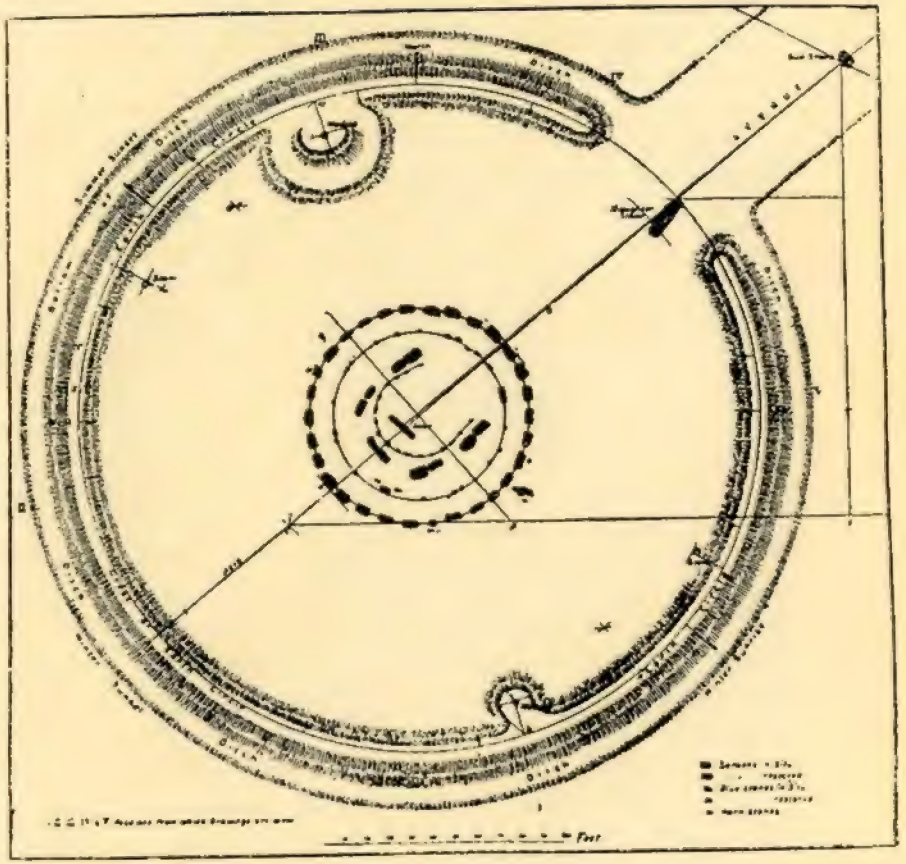
a person's birth. They have nothing to do with the stars. And the so-called scientific astrology which seeks to provide a statistical proof for the traditional methods is equally unsatisfactory. The number of cases taken so that they shall provide the required answer is too small. If really large numbers of examples are taken we find that the frequency of births is fairly equal throughout the year without special preference for any given month. It is entirely



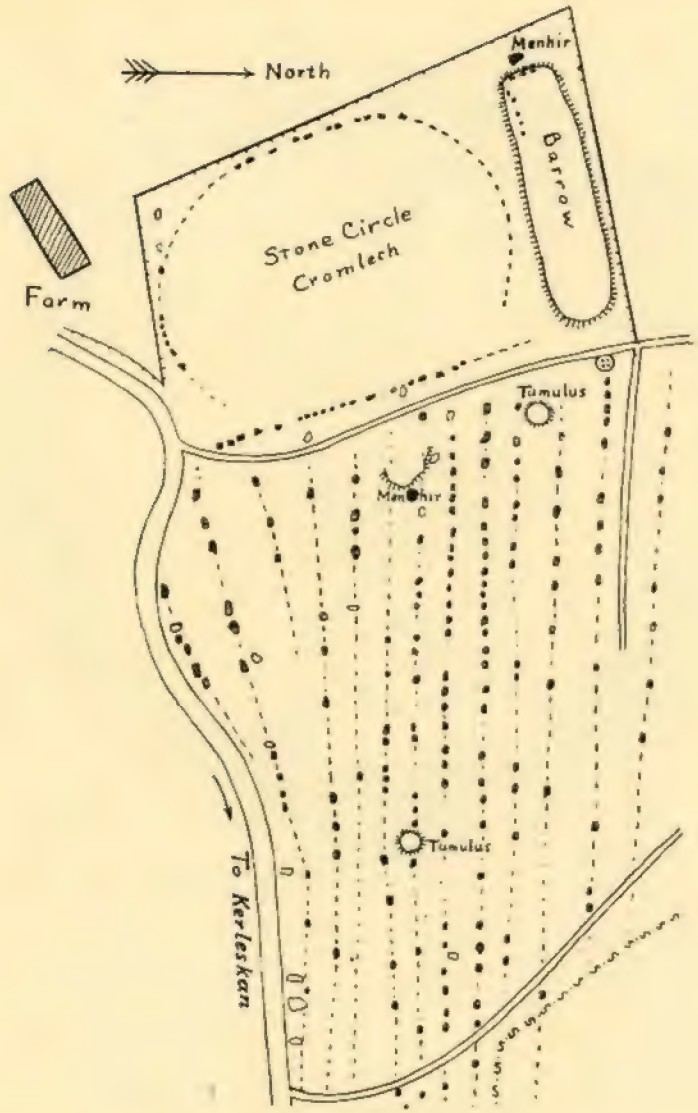
24. Frequency of Births of Astronomers and of Mathematicians in the different Decans

different with the natural laws, where the curve becomes more pronounced the greater the number of cases observed.

If we want to test the traditional methods the birthdays of astronomers provide a specially suitable occasion. What other professional group can be more directly subject to heavenly influences than astronomers who, by profession and inclination, chiefly concern themselves with the events of the sky? The manual of Hermes Trismegistos which we mentioned above contains the Egyptian teaching on the way in which births are distributed



XII. *Plan of Stonehenge*

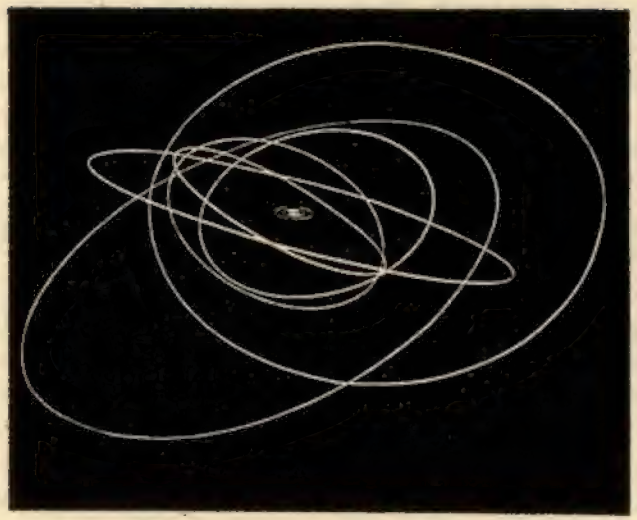


XIII. *Stone avenue and stone circle near Kerkestan, Britanny*

among the signs of the Zodiac. On the other hand, Müller's *Mathematician's Who's Who* and the portrait gallery of the Astronomical Society comprise 1672 birthdays, which should be a sufficient number for testing the tradition. Fig. 24 shows that there is no similarity between the two curves. In all probability the curve for astronomers and mathematicians would approximate even more closely to a straight line if a greater number of instances were to be collected.

The astrologers were not satisfied with the seven planets—Sun, Moon, Mercury, Venus, Mars, Jupiter and Saturn—but also used the planets Uranus, Neptune and Pluto, which had been discovered since the eighteenth century. They chose to believe that in this way they were keeping in step with astronomical developments. But their method destroys the older tradition, which confined itself throughout to the seven planets whose names survive in the days of the week. At the same time astrologers were faced with a possibly unexpected dilemma. Neptune is, of course, a small and slowly-moving planet. It is too weak to be seen by the naked eye. Pluto is so small that its diameter can be perceived only through the largest telescopes. Moreover, it moves so slowly along the skies that it can hardly be properly described as a planet. On the other hand, thousands of minor planets exist between Mars and Jupiter; if the fact of motion is the decisive characteristic of a planet, why are these minor planets not used by the astrologers? What an opportunity they are missing! The minor planets are named after towns or countries; many have feminine names. What an opening this provides: what could not the position as between 'Mars' and 'Russia' and 'America' signify? Or take non-political interests. How could we interpret the relationship between 'Melpomene', 'Thalia', or 'Urania' and the artist 'Mercury'? Or, again, if Bertha or Tusnelda would like to meet the Olympic victor named 'the Sun', in Bamberg or Heidelberg, the courses of the planets bearing these names should throw light on the matter.

And why is nothing done about the numerous moons? Why is the earth's satellite the only one consulted? How easy it would be



25. Orbits of the twelve Moons of Jupiter

to make political forecasts if the Prime Minister Jupiter happened to be in a favourable position towards his Ministers (the four brightest of the Jupiter moons) or towards the deputies, the remaining weaker Jupiter moons (Fig. 25).

And the continual variations in the appearance and strength of the stars—why do the astrologers never use them? Why do they waste these myriad opportunities?

No ideas, no discrimination, no understanding of modern astronomy—these were the astrologer's characteristics. The royal art of astrology degenerated into fortune-telling.

• VIII •

DO THE STARS DOMINATE CHRISTENDOM?

CHRISTIANITY was founded at a time when it was customary to consult astrologers and other fortune-tellers about any important decision. Men were caught up in a network of interrelations between heaven and earth, and only the astrologers knew the correct relationship. The latter for their part maintained that human activities were predetermined by the stars in their courses. Accordingly it was impossible for man to alter his fate. At this moment Christianity appeared, bringing hopes of salvation and gathering thousands of adherents. This happened at a period when all earthly events were regarded as being determined by the stars. Hence it is not surprising if the birth and death of Christ were regarded as being closely connected with phenomena in the sky, as had been done with Mithridates Eupator and with Julius Caesar. The story of the Christmas Star is familiar to all. In the Gospel of St. Matthew (Chap. 2) we read how the Wise Men came to Jerusalem, 'saying: "Where is He that is born King of the Jews? For we have seen His star in the East and are come to worship Him." ... Then Herod, when he had privily called the Wise Men, enquired of them diligently what time the star appeared. ... When they heard the King they departed; and lo, the Star which they saw in the East went before them, till it came and stood over where the young child was.'

These words have been interpreted in many different ways. What is certain is that the conventional beginning of the Christian era is incorrect. The birth of Christ cannot have taken place at the time generally assumed; it must have been a few years earlier. Herod died in the Spring of 4 B.C., and the census ordered by

Augustus began in 10 B.C. or 9 B.C. Christ must therefore have been born between 10 B.C. and 4 B.C. Kepler and others have assumed that the Christmas Star was really a conjunction of Jupiter and Saturn, which occurred in 7 B.C. This, however, is refuted by the clear mention of 'the Star' in the Gospel. Possibly what the Wise Men saw was a new star. This is a tenable hypothesis, although no such appearance has been recorded for this period; but the reports relating to those years are scanty, and the mere absence of such a mention is inconclusive. Another possibility is that the Star of the Jews (Saturn) was meant. Saturn had its early rising in Mesopotamia in the first week of April, 7 B.C. The course taken by the Christmas Star, according to St. Matthew, agreed with that of Saturn in the period from October 10 to December 15, 7 B.C. If the early rising of Saturn indicates the time of birth, this took place early in April, 7 B.C., which agrees with Hippolytus's statement that Christ was born on April 2.

Portents in the heavens were also recorded for the death of Christ. He was condemned and crucified on Friday, the 15th Nisan, the Passover meal having taken place the day before. The date of the 15th Nisan and of the Passover celebration can be determined if we know the possible years for the Crucifixion. The only possible years are, in fact, A.D. 30 to 33. The years A.D. 31 to 33 can be eliminated, so that only A.D. 30 remains. In this year the first day of Nisan was on March 24, so that the 15th day of Nisan was on April 7, A.D, 30. On this day there was a full moon; consequently an eclipse of the sun was impossible. Matthew, Mark and Luke simply record that there was darkness from the 6th to the 9th hour, and Luke adds 'and the sun was darkened'. This could have been caused by dense clouds; and since we are further told that the veil of the Temple was rent, there may have been a storm. The later view that the darkness was caused by an eclipse of the sun may be due to recollections of the terrifying eclipse which took place on November 24, A.D. 29. On this occasion a full eclipse took place at noon in Syria; even at Jerusalem it must

have been deeply impressive. Admittedly over four months elapsed from the eclipse to the Crucifixion; but such differences have never troubled astrologers.

The sacred numbers 4, 7 and 12 were taken over by Christianity from Judaism. There are four corners of the earth and four Gospels, twelve prophets and twelve disciples, seven candlesticks, churches, spirits, planets and days of the week. The gates of the Temple were directed towards the four cardinal points. The long veil (of Babylonian origin) displayed the colours of the four elements, while the embroidery on it represented the entire heavens, with the exception of the Zodiac. The Christian Church of the Sepulchre in Jerusalem was also constructed in reference to the four cardinal points. It was circular, with two Eastern entrances. On the outside there were three niches with altars—on the Northern, Western or Southern aspects. The Holy of Holies was approached from the East. The Sepulchre is in an East-West direction, facing towards the East. Here is another survival of pagan sun worship. Early Christian churches, like St. John's at Ephesus (second century), the Church of the Miracle of Loaves at Tabgha on the Lake of Genezareth, and the Dome and Our Lady's Church at Treves (fourth century) are so constructed that the faithful look Eastward beyond the altar.

In 335 Constantine the Great reached a momentous decision: the celebration of Christ's birthday was moved from January 6 to December 25; Christ thus replaced the Sun God whose feast had previously taken place on December 25. Accordingly Christ (like the Sun God) entered into activity at the Winter Solstice, thus forming a counterpart to John the Baptist, whose activity begins with the Summer Solstice. A long struggle now began to be waged by the Church against the growing influence of astrology. Various councils endeavoured to prohibit the observation of unlucky days and to counteract the belief that the planets and the new moon exerted a special influence. But their success was short-lived, and these superstitions revived. St. Augustine had declared that the stars were powerless against God's omnipotence and

man's free will, though he did admit that the stars could exert an influence on the sublunary world, that the sun affected the seasons and that the moon acted upon the tides and on the growth of certain animals. This view may explain the relative feebleness of the campaign against astrology. Thus it was possible that, while the Church forbade the faithful to wait for the new moon before a marriage was celebrated or the foundation stone of a house was laid, Charlemagne and his son Louis read their impending deaths from events in the skies while the Ottonian Empresses had their caskets decorated with the signs of the Zodiac, each sign being worked above one of the twelve Apostles—as though there had been some connection between the Apostles and the signs. On a Carolingian Crucifixion we find the sun and moon represented, not by mourning heads, but by the pagan god Sol on his chariot and the goddess Luna in her carriage with her team of cows. Then again, Mary is placed among the heavenly bodies, being identified with the Polar Star (Stella Maris) or with the Morning Star (Stella Matutina). A rather naïve instance of the way in which Christian and pagan ideas were employed is provided by the cloak of the Emperor Henry II. This was a special coat, probably made for the Coronation in 1014; it displayed, side by side, Christian figures and figures representing the ancient constellations and the starry sky, and was intended to recall the ancient idea that the Emperor, being master of the world, wore a coat of stars like many of the pagan divinities. One remarkable point is that the pattern of the coat showed a special relation between the Moon and the Crab, and the Moon and the Scorpion, relationships which are meaningless except in an astrological sense—a sufficiently remarkable way to decorate the coronation coat of a Christian Emperor. From this point astrology was in the ascendant. In the twelfth century this was reflected in the Toledo Letters, and in the horoscopes which were cast in accordance with Christian suppositions.

Not a little perturbation was caused by the Toledo Letters, with their prophecies based on the conjunction of all the planets in a single sign and by those other prophecies which were based

on the conjunction of two planets. But if people were frightened, the science of astronomy was fostered. Christian astronomers learned the use of the traditional tables of planets, if only to check the correctness of the Toledo Letters; they discovered the errors contained in the tables, and by observing the planets discovered that the Ptolemaic ideas were invalid. They became acquainted with the sky and the constellations, and learnt how to use their own instruments to determine the planets' position. The Toledo Letters and other prophecies based on the conjunction of certain planets had another advantage: they caused astronomers to check the accuracy of their forecasts. After the fifteenth century attention was specially concentrated on meteorological observations; meteorological records began to be kept; it became important to test whether the weather forecasts which formed the main contents of the prognostications in the calendars were actually correct. Pico de Mirandola wrote some time before 1494: 'I spent a whole winter in my country house where I wrote this work, observing the weather day by day and checking against the astrological forecast. May I be punished if I do not tell the truth: I made observations on over 130 days; and there were not more than six or seven occasions when the weather agreed with the forecasts.'

The case was different with horoscopes. We saw above that the different sub-divisions of the houses and the valuation of the planets and signs gave to astrologers openings for widely different interpretations in reading horoscopes; moreover, the figures which were used for them differed according to the tables employed by the astrologer. If he did not begin from the date of birth, which it was permissible to correct, and preferred to start from the date of conception, a fresh element of arbitrariness was introduced. A debate on this subject was held in 1467, before Matthias Corvinus of Hungary, the disputants being the Astrologer Royal, Martin Ilkush, and Master John of Glogau, who came from Cracow. The question was, to find the date when the son (born April 26, 1467) of the Count of Rosgon had been begotten. Ilkush, using the position of the moon at the date of birth,

had calculated that the date was July 17, 1466. This result was indignantly disputed by John of Glogau, who showed that the right way was to start from the full moon immediately preceding the day of birth, which would give July 18, 1466, as the date of conception. Each of the disputants could quote authorities: John cited Ptolemy, Ilkush took his stand on Hermes. The father remained incommunicative about the date of begetting; the facts could not, therefore, be checked, and the whole debate came to nothing except that it brought John of Glogau a fee of a hundred florins. Many years later Georg Rollenhagen discovered that Hermes's formula was incorrect, as he showed from the respective dates of the conception and birth of a number of children.

The uncertainties attending the interpretation of horoscopes caused large collections of horoscopes of every kind to be formed. This practice began late in the fifteenth century. To facilitate use some were arranged by professions; others by the position of the sun. Some went beyond the bare astronomical data and listed the actual events in the lives of the persons concerned. In every instance the position of the planets was taken into consideration; more rarely, that of the stars like Algol or Alhabor. Horoscopes virtually ceased to be cast after the seventeenth century.

The Toledo Letters and the use of horoscopes could not have done great harm to Christianity. They could be regarded as irritating by-products of Graeco-Roman and Arab astronomy, though admittedly the theory of astrology conflicted with the Christian doctrine of free will. Dangers began to arise only when people began to believe that the chief persons of the Christian faith were subordinated to the influence of the stars and began to draw their own conclusions with regard to ecclesiastical matters. The Arabian Albumasar had foretold the coming of Christianity through a grand conjunction of the planets in the sign of the Virgin; he had also foretold its end for some period after 1460. In the twelfth century Bernard Sylvester and, later, Roger Bacon, taught that Christ was subordinated to the influences of the stars and held that His birth was determined by their position.

In Italy the growing power of astrologers acted as a challenge to their opponents. Petrarch wrote: 'Why do you debase heaven and earth and mock men in vain? Why place on the shining stars the burden of your petty laws? Why make men who were born free the slaves of the unfeeling stars?' And Heinrich von Langenstein wrote that every conjunction could be calculated in advance, but that it was pure accident if the conclusions drawn from the calculations proved correct.

The Italian Princes kept their own Court astrologers. The departure of princely personages, the reception of foreign ambassadors, the beginning of wars, and the laying of foundation stones for public buildings—all these were governed by the position of the stars. The Pazzi Chapel and the Sacristry of San Lorenzo in Florence have diagrams of the stars painted on their ceilings, recording for later generations the date of the final sitting of the Council which, on July 6, 1436, resolved upon the definitive union between the Roman and Greek Churches. Most of the Italian generals followed their astrologers' advice, as Wallenstein did later and Hitler with his companions in crime in our day. The Salone Palace in Padua and the Schifanoia Palace in Ferrara were decorated with astrological pictures. Even the princes of the Church followed the fashion. Since the thirteenth century cardinals and bishops practised astrology. Innocent VIII consulted an astrologer about an illness; Julius II gave instructions to have a propitious time for his Coronation and his return from Bologna worked out from the stars. Astrology flourished particularly in the time of Leo X. His horoscope was cast with such success that the chief events of his rule were foretold—or so we are informed —to the nearest day. Paul III called on his astrologers to tell him the hour suitable for holding consistories. This was the period when Luther was condemning astrology, while his friend Melanchthon was approving it.

When the heads of the Christian churches were thus allowing astrologers to regulate their activities, it was not surprising that ordinary Christians were fond of consulting the calendar on mat-

ters concerning public events, health or the weather, and had recourse to the many rules contained in the calendars to foretell the future of their children. Everything—the day on which to start a journey, for sowing and even for having your hair cut—was supposed to be subject to the stars' influence. The appropriate time for having oneself bled was supposed to be determined by the position of the moon in one or other of the signs of the Zodiac; human figures showing the signs and their inter-relationships were often drawn to help in working this out (Plate VIII). A flourishing trade used to be done in calendars and prognostications. The difference between these Christian practices and those of the Romans at the beginning of the era must have been small. Free will had almost been forgotten. But at this moment when astrology had reached the height of its popularity a sudden change occurred. The traditional attitude began to be questioned. The first beginnings of the process could be observed in the fourteenth century, when Heinrich von Langenstein and Master Julmann proved that the courses assigned to the planets by Ptolemy conflicted with the observed facts and must therefore be incorrect. The battle between observation on the one hand and theory and tradition on the other was engaged; it ended with the Copernican solution, which deposed the earth from its position as the central point of the universe and made it a satellite of the sun. It was to the sun that the succession went. All this entailed a complete reassessment of values. Hitherto people had been accustomed to contemplate the things going on in the skies as though they formed a display to be watched from a seat in the stalls. The planets were actors and their messages were listened to like actors' speeches. Now, quite suddenly, men and their little world found themselves simply a part of the surrounding universe. They were not outside spectators; the earth was like a member of the public in an open square where people and vehicles are in constant and restless motion. The standards were changed; the earth shrunk; the sun was vastly expanded; and the skies, which had formed a backcloth against which the stars executed their motions, dis-

appeared and were replaced by three-dimensional space. The Milky Way ceased to be a picturesque ribbon stretched across the sky: the telescope showed that it was an agglomeration of a multitude of stars. New stars appeared, others disappeared. Everything was changed; there was no rest. The result of all this was that astrology lost its basis. After all, observation brought its own results. How was it possible to imagine Saturn as an old man or a criminal if the telescope showed a shining disc with a luminous ring and moons rotating around it? How could the influence of the sun or the planets be correctly calculated in a horoscope when observation showed that the sun was a gigantic source of heat and the planets small mirrors of the sun? Astrology had ceased to be a danger for Christianity.

• IX •

THE STARRY SKY—OBSERVATION AND THEORY

ONE reason why it was so hard to observe the phenomena in the sky lies in the fact that the observer cannot approach and touch the celestial bodies. The telescope succeeds only in bringing these objects nearer; they are never really at hand. This is what differentiates the astronomer from the physicist and the chemist, the zoologist and the botanist. Moreover, astronomical studies require clear skies; and the dazzling brightness of the sun makes it impossible, while the sun is in the skies, to observe the weaker luminaries. Substantial difficulties must therefore be overcome before astronomical events can be studied or explained. Again, the aspect of the heavens differs from day to day. Each day the stars and constellations rise earlier; the movements of the planets increase the confusion, and the moon, with its mysterious waxing and waning, makes confusion worse confounded. So many things are going on in the heavens that men suspect a secret behind them and try to interpret their meaning. Others take a different view and adopt Goethe's lines:

> 'We do not desire the stars
> But we do enjoy their splendour
> We gaze up with delight
> When the night is serene.'

The pleasure felt in watching the skies and the reverence inspired by the astronomical processes cause men to erect observatories and give them a popularity very different from that enjoyed by geological and meteorological institutes or by chemical and physical laboratories.

The process of explaining the astronomical events was so difficult because, while the stars keep to their courses, the planets follow different ways. It was gradually realised that it was impracticable to use the earth as a plane of reference, and that a number of different circles must be distinguished in the sky. Eventually the horizon, the equator and the Zodiac were established as the three important circles, together with their appropriate pairs of celestial co-ordinates. At a later stage it became clear that certain difficulties remained. Centuries of observation showed that the path of the sun on the celestial sphere was gradually displaced relatively to the stars and the terrestrial equator. A new element of uncertainty was thus added. In this way new observations led to new discoveries and to new explanations. From the facts observed on this earth ideas were drawn which seemed appropriate for furnishing explanations of the celestial events. Eclipses were explained by saying that some monster, a dragon for instance, devoured the sun or the moon. The sky with its stars was explained by assuming that the earth was a flat disc with a gigantic tent above it, its four uprights corresponding to the four cardinal points and its surface being covered with the constellations. Later the revolutions of the stars were assimilated to the movement of a potter's wheel, to the axis of which circular bands were supposed to be attached, each bearing a planet. Next, it was assumed that the earth was a sphere fixed in space, with the planets in their spheres revolving around it and the starry sky in the shape of a hollow sphere forming the ultimate limit. It was constantly assumed that the heavenly bodies were globular and that their movement must be circular and uniform. It was only when Copernicus took the decisive step of assuming that the earth was not the centre of the planetary system that it became possible to assume and eventually demonstrate that the courses of the planets were elliptical and that the heavenly bodies had a flattened shape. The domination of the circle and the globe was broken. New mathematical ideas could be used to explain the astronomical phenomena.

The fact that the heavenly bodies can never be reached explains

not only the difficulty of studying them, but also the remarkable vitality which some of the most primitive explanations enjoy. In attempting to establish a relationship between the planets and the signs of the Zodiac on the one hand, and the terrestrial events on the other, people cheerfully distorted the observed facts. They did not hesitate to assume that Mercury and Venus were at a wholly impossible distance from the sun. The same happened with reference to the order of the planets as patrons of the hour. The facts were distorted to fit the theory. The compulsion to follow ancient ways of thought blinds people to the results of modern studies of the solar system and particularly of the planets. Once people are convinced that the new moon brings a change in the weather, or that knives rust at the full moon, they are immune to mere facts. They are like men attacking an armoured vehicle with bows and arrows.

Observation is the only way of allowing people to understand the events in the skies. The phases of the moon were used to measure the lapse of time; the next stage was to calculate the advent of eclipses from the movements of the sun and moon; but all this was possible only if the coming of the new moon was noted, as is still the case in Mahommedan countries, and if the formulae needed for the calculation of eclipses were derived from such observations. This kind of observation applied to sun and moon allowed improvements in the Roman and Christian calendars to be made; in this way the Julian and the Gregorian calendars were constructed.

Other observations related to the movements of the planets, they were important since the planets in their courses had been held from time immemorial to govern the destinies of nations and individuals. Eventually the positions of the stars came to be exactly determined; and finally Hipparchus set up his catalogue of stars. The limits of what was permitted had thus been reached. Socrates had uttered a warning against studying the movements of the planets; but this warning was unheeded. Even the Greek zeal for knowledge, however, stopped short of measuring the positions of the stars—an unholy undertaking. It was reserved to a later age,

beginning with the great migrations in Western Europe, to use observation as a means of obtaining a deeper understanding of the events in the heavens. Observation now gained a fresh significance. Instruments and, later, observatories were constructed to assist observation; and nobody questioned the propriety of unveiling the secrets of the heavens in this way. This method flourished at the time of Regiomontanus; but in a rudimentary form it goes back to a much earlier stage. In the eleventh century, when William of Hirsau taught astronomy at the monastery of St. Emmeram, the fine instrument shown on Plate IX was produced at Ratisbon. It shows a youth kneeling and looking towards the Pole; the reverse represents the axis of the world and a section of the chief circles in the skies, allowing the student to inform himself on their positions in the heavens. In Ratisbon also the figure of a young man observing the sun can be seen on the bridge built there in the twelfth century. Figures of this kind later became common. They can still be found at Strasbourg, and Ruffach. Scientific observation now began to replace astrology.

· X ·

MODERN ASTRONOMY

IT began with a fraud. In order to obtain agreement between his observations and his theory Copernicus altered a number of the former, including some of the observations of Mercury made at Nuremberg. Yet he was no worse than his contemporaries. After all it was common practice when casting horoscopes to change the date of birth until certain known events in the person's life could be read from the horoscope. Nor did the Renaissance frown on such practices. In the universities the girls going to the pump would salute each other in Latin; a number of Germans Latinised or Grecised their names until the original could barely be recognised, as with Dasypodius and Clavius: surely this also was a distortion of the facts. When Copernicus opened Ptolemy's Manual, that pattern of astronomical rectitude, it could not be long before he discovered that the great Ptolemy himself sometimes drew conclusions from his observations which were intelligible only if it was assumed that one function of the results was to confirm his theory. But Copernicus was not a Ptolemy. He was in a dilemma. On the one hand he realised that Ptolemy could hardly be blamed for twisting the facts to fit the theory if he, Copernicus, was doing the same thing; on the other hand, he was anxious to give his revolutionary ideas the widest publicity. He hesitated, and tried to provide in new observations a better basis for his theory. His controversy with Bishop Dantiscus and his illness prevented him from carrying through this plan, and his work was published in an unfinished state. Kepler, a young man at the time, pointed out the defects in the following passage:

'Copernicus had a certain human weakness in accepting any

figures which favoured his wishes and supported his theories, as the diligent reader can easily prove by perusing Copernicus's works. . . . He was wont to select the results reached by Walther, Ptolemy and others in such a way as to favour his own calculations, and accordingly did not hesitate when dealing with measurements of time to neglect or alter time differences of several hours, or angular differences of up to 15 minutes. . . . He took over without change from Ptolemy many items which, by his own admission, ought to have been altered; in other instances he introduced arbitrary alterations. This is the way in which he laid the foundations of the new astronomy.'

Kepler's own reflections on these subjects proved fruitful. No doubt it was the recollection of Copernicus's method that caused him not to violate correct observations like those made by Brahe, and to make his theories accord with the facts. The laws governing the movements of the planets were the results of these exacting labours.

While Kepler was striving to discover these new laws, the human field of vision was enormously extended by the invention of the telescope. The lens, hitherto used as a magnifying glass or as a simple ornament, became an instrument for bringing distant objects nearer. It was not long before its value to astronomy became evident. The discovery of the Jupiter moons, of the Mountains of the Moon, of the crescent shape of Venus, of the peculiar configuration of Saturn, of the sunspots, and of the fact that the Milky Way was an agglomeration of stars—all this, though it did not prove that Copernicus had been right, did signify that nature was richer than had been assumed. The telescope allowed people —in the first instance those of Western Europe—to study the stars and their movements far better than the naked eye permitted. Moreover, the employment of the telescope could be extended almost without limit. Next, the mirror was introduced, an instrument destined to play an increasingly important part. A further advance came with the employment of photography. This

made it possible to provide a uniform foundation for a wide range of studies—a foundation capable of being checked and tested at any time. In this way a whole range of studies on variable stars, on their distribution and on the appearance of new stars became possible. Without photographic records the study of remote objects like certain stellar clusters, nebulae and spiral nebulae, is impossible.

Astronomy differs from other natural sciences in that the objects of its study cannot be investigated directly or subjected to experiment. The astronomer is confined to studying the light which the stars send him, and to choosing appropriate observatories and instruments to make his studies as fruitful as possible. The old system of discarding facts which did not support the preconceived theories was now impossible. Until the seventeenth century this practice had been followed; now all this was changed. The theory of probability was used to devise a method for using a multiplicity of observations whence improved results were derived. In this way it became possible in the course of the nineteenth century substantially to increase the degree of exactitude with which the positions of the planets were determined. At the same time the methods for eliminating or compensating faults in the instruments were improved. One important problem was to allow for the observer's own idiosyncracies. It was found that these idiosyncracies affected his results in various ways. Bessel was the first to draw attention to this, and to show that Maskelyne had been wrong in blaming a colleague because he had stated that a star had disappeared behind the cross wires at a different time from that observed by Maskelyne himself. Bessel was able to show that this moment differs with different observers—in other words, that each observer has a different personal equation. Careful observation showed that the value of this difference depends, among other things, on the brightness of the star. Special measures were needed to allow for the personal equation. The same applied to the observation of double stars.

Visual idiosyncracies are particularly important when the

brightness of stars has to be measured. The Greeks described the brightest stars as stars of the first magnitude, and the feeblest as those of the sixth magnitude. These descriptions were not based on measurements; they simply meant that stars of the first magnitude were those which first became visible at twilight while those of the sixth magnitude became visible only when darkness was complete. When, in the nineteenth century, people began to measure brightness and to compare the results thus found with the estimated magnitudes, it was found that there was a striking relationship between the magnitudes discovered and the estimates—a relationship resembling that discovered earlier by Weber and Fechner to exist between sensory perceptions and stimuli. (This was later formulated in their law of sensibility.) Detailed studies based on a very large number of observations show that the colour as well as the brightness of the star was relevant. Other curious observations were made. It was found that observers who studied the brightness of stars over a long series of years underwent a change. Their eyes were at first relatively insensitive; eventually practice gave them a high degree of sensitivity and this remained stable for a large number of years, declining rapidly only in extreme old age. Where two observers operated together it was found that the more brilliant and leading member of the pair had a better sense of colour but was less exact than the junior partner, who kept a better average—as though the more highly gifted personality was in a continuous process of adaptation as well as of instinctive groping towards the object observed. The achievements and name acquired by astronomy are due to these studies of the skies and to these investigations into the subjective element. This was achieved despite the relatively unfavourable conditions ruling in the countries where astronomy is most vigorously pursued. Clouds are apt to be frequent and the light coming from cities makes work difficult, if not impossible. A number of important telescopes became out of date before they had been properly used. Hence came the idea of building observatories specially devoted to the study of the skies and situated with this primary

object in view. In England the Greenwich observatory was moved to Hurstmonceaux, and the Norman Lockyer observatory was erected near Sidmouth, in conformity with this idea. In the United States, where large grants are readily available, other methods could be practised. Observatories were built on lofty summits, thus avoiding the poor visibility at the lower levels and the interference of light from big cities. At the same time better use could be made of clear nights when the sky was cloudless. Similar observatories have been built in South America and South Africa to observe the Southern skies. The American example was imitated elsewhere too. Thus it came about that research observatories were built all over the globe and the idea was generally accepted that the most favourable sites must be found for them. This is particularly important for observing full eclipses of the sun. These are visible only along a narrow band over the surface of the earth. Accordingly, great importance was attached to selecting the best sites and the most appropriate telescopes, particularly now that Einstein's Theory of Relativity requires proof that the light coming from the stars is deflected by passing in the neighbourhood of the sun.

Astronomical observation is most successful when a given event is observed from a maximum number of points. Even the old observations made by the Chinese and Japanese were of great help to European observers. Today this is even more important. Thus it came about that from the seventeenth century onwards astronomers have informed each other of important impending events like the transit of Mercury across the sun or of a new appearance of Mira Ceti. The different observatories are in contact and exchange publications. The feeling of solidarity is so powerful that even the two World Wars did not put an end to the collaboration among astronomers, who continued to exchange information and greetings. Astronomers meet at conferences to discuss important questions and to consider joint operations. Such works, however, have usually not been undertaken under a favouring star. Often enough an astronomer promises to collaborate and

then finds himself unable to keep his promise. Such was Bessel's experience when he prepared and attempted to carry through the great task of publishing the Berlin Star Atlas. His correspondence shows that enthusiasm quickly waned and the members of his team were slow in preparing and delivering their maps. Later undertakings, too—the compilation of catalogues of stellar positions, of collected photographs or of manuals—confirm the experience gathered in other branches of science that undertakings of this kind are apt to suffer from the carelessness or sloth of individual members of the team. It is impracticable to drill these people as members of an athletic team are drilled. More useful work is done where one astronomer leads a resident team, as was done with the Star Catalogues compiled at Bonn and at Cordoba. To these people we are indebted for the star catalogues which remain essential for many types of observation. To take another instance: astronomers are indebted to one individual—Franklin-Adams—for the comprehensive photographic atlases, the only ones of their kind, the result of photographs taken in England and South Africa and, after his death, elsewhere. The way in which this one man devoted himself to his work must cause universal admiration. Lovers of the stars like Franklin-Adams or Herschel have done great work to advance astronomy.

What is it that causes men to contemplate the sky and to observe the movements of its bodies? Throughout the centuries astronomers have readily given up their nights to watch the heavens. In Egypt, Babylon and China, it was admittedly a duty for the priests to keep the skies under observation for any striking or dangerous apparitions. But there was also an element of pleasure in these observations, an element particularly notable in Greece. Anaxagoras (499–428 B.C.) said that it was better to live than never to have been born, for the living man could contemplate the heavens and the universe. Euripides (about 410 B.C.) wrote:

'Happy the man who has experienced
The joys of untrammeled search after knowledge.

There is nothing to draw him into the tedious business of
State
Or where injustice prevails.

'Pensively he watches the never-ageing structure of eternal
nature
Asking why it arose and whence and how.
In thought and in deed
Such a man is free of all contagion of impurity.'

We saw above what Pliny said about the way in which Hipparchus was led to study the stars. And Seneca exclaimed: 'Is there a more noble study or a more useful part of knowledge than that relating to the nature of the stars and the planets?' The views of Ptolemy were much the same. In the preface to his great work on astronomy he wrote:

'Now so far as a virtuous manner of life in all respects is concerned, I think that this science is specially calculated to train the mind for virtuous conduct. Astronomy provides us with a divine pattern of uniformity, firm order, harmony and simplicity, and thus instils in those who follow it a love of this divine beauty, gradually making a kindred frame of mind into a sort of second nature.'

About A.D. 1000 the Arab scholar Abu Hadjan al Taubidi wrote in the following terms about the value of astronomy and astrology:

'In studying the stars we follow two distinct aims: first, to discover the behaviour of the stars in their different motions, their standing still, their risings and settings, their conjunctions, and in their other, different, positions. The study of these subjects resembles that of a householder who acquaints himself with every corner of his house, with the details of his furniture and other possessions, with the number of its inhabitants and with his neigh-

bourhood. Thus contemplating the stars he is seized by a sense of wonder which opens his heart, strengthens his belief in the unity of God, enriches his teaching and fills his sight with longing. Secondly, the searcher endeavours to gain understanding of the signs pointing to future events. These are studies of great value—to examine the constellations, the subtle way in which their influences work, the changing shapes in the skies, the discovery of the secret of fate, the remote workings of the will of destiny, and the law which governs the world. He who would pursue this aim must spend much trouble on it. Yet his success will be small and it is more common to miss than to hit the mark.'

There are few later parallels in Europe to these earlier Greek and Arabic views. Circumstances have changed. The errors to which ecclesiastical chronology was subject were known. It had become necessary to observe the skies themselves (Plate IX). In consequence repeated attempts were made to improve by observation the accepted tables setting out the movements of the planets. Regiomontanus held that if a new astronomy was to be built up, many years of systematic observation would be needed. His disciple, Bernard Walther, continued Regiomontanus's method until his death in 1504, producing the first ample and systematic series of planetary observations. His example was followed by Brahe, who produced the foundations on which Kepler built in his turn. Since this period modern astronomy has been the product not of interpretations, but of actual observations. It was the latter that gained general esteem, with the result that larger and larger observatories and telescopes were constructed, producing a whole mass of catalogued data as well as numerous maps and photographs.

• XI •

ABERRATIONS

WAS Ptolemy's theory of the planets just an aberration? It would be too much to say so; on the contrary, it was undoubtedly a substantial advance. When Ptolemy wrote, the theory had only just been abandoned that the earth was the centre of the universe with the heavenly spheres each bearing a planet revolving around it. Earlier still the earth was regarded as a flat disc floating in an ocean of space with the stars revolving around the axis of the heavens as though attached to it by bands. We thus see a continuous adaptation of theory to the processes in the sky, these being interpreted by the observers as best they can. Socrates had warned his disciples against the theory of the planets. He thought it was vain and aimless to study the planets, since their movements could not in any case be revealed; the gods' displeasure would be aroused by attempts to explain what they did not wish to be explained. The advance achieved later by Greek astronomy is shown by Ptolemy's successful attempt five hundred years later to provide a satisfactory theory of planetary motion. In doing so he had to neglect earlier Greek attempts to explain these motions by a totally different theory. Yet his work on astronomy was a masterpiece and for a thousand years it was regarded as the last word until eventually weaknesses in his theory became apparent and new observations made by Copernicus led astronomers to base their theories on the earlier views which Ptolemy had rejected. Eventually Kepler formulated the theory that the paths of the planets are of an elliptical shape.

The theory of the ovoid shape of the earth can be regarded as another aberration. It gained currency about 1700. Huygens and Newton had been led by theoretical considerations to deduce that

the earth was flattened at the poles. Observations seemed to prove the contrary, as Eisenschmidt of Strasbourg thought he proved in 1691. Cassini's observations seemed to confirm the view that the earth was ovoid and not flattened. When, finally, the Paris Academy of Sciences in 1735 awarded a prize to the work of Bernoulli, who maintained that theory required the ovoid shape, the last word seemed to have been said. New measurements in Peru and Lapland were necessary to demonstrate the flattening. It was natural that Maupertuis, who took part in the Lapland observations, consented to have himself depicted flattening the earth with his hand (Plate X).

Later in the eighteenth century the scientific world of Paris was amused when a report was published that the Town Council of Juillac had reported to the Academy a fall of stones, confirmed by three hundred witnesses. This seemed altogether too fantastic. Admittedly earlier reports about such phenomena existed, but they had always been regarded as absurd. How were stones to reach the earth out of the blue? A monstrous idea. The physicist Bertholon wrote in a periodical: 'How sad is it to find a town council sanctioning fairy-tales. Those who believe in these myths have our sympathy. What are we to add to this report? All that can be said will readily occur to the philosophic reader perusing this official report of an obvious falsity, a physically impossible event.' The belief that stones could not drop from the skies survived for another ten years. Eventually the sceptics were confounded by Biot (1774–1862), who published a report about stones which had fallen at L'Aigle on April 26, 1803. Biot established a connection between the stones and a fireball which had in fact been observed. After this it was permissible in France to believe in meteorites.

One of the wildest aberrations consisted in the theory of orientation. In the erection of temples and tombs many different peoples took the cardinal points into consideration. Strict observation of these points was practised when the Pyramids were built. In the last centuries B.C. the rising of one of the stars in the Great

Bear was observed in the construction of Egyptian temples—with what degree of accuracy we do not know. The Christian Church had a general preference for an easterly direction, without troubling much about a high degree of accuracy. Sometimes churches were built facing sunrise at the time of the solstice. A more exact observation of the point of sunrise was later accepted by English Freemasonry; it was reinforced by references to the remains at Stonehenge. On Salisbury Plain the traveller can observe a grandiose structure consisting of gigantic stones standing upright or lying prone. Originally these stones formed two rows in the shape of a horseshoe within two concentric circles of stones. In the centre of the horseshoes a large stone lies which is described as the altar. As is shown on Plate XII the entire structure is contained within a circular earthwork with two bays and two stones. The point of intersection of the lines joining these objects lies at the centre of the earthwork and of the circles of stones. The earthwork has an opening towards the axis of the horseshoe, allowing a ceremonial road to lead direct to the altar. In the middle of this road the slaughter stone lies; another lofty stone called the Heel Stone is situated there. Here, at the summer solstice, large crowds await the sun, which can be seen from the altar stone rising above the Heel Stone; meanwhile school teachers disguised as Druids chant ancient songs. This custom, however, is not old. Stonehenge has at all times exerted a fascination. In the Celtic Sagas it is described as a tomb. It was promoted to be a temple of the sun by the English Freemasons, who were anxious to prove that sun worship had been practised in England at the earliest times. This involved a number of difficulties. For instance, when one looks from between the two uprights and over the altar stone towards the Heel Stone, the line of vision does not point towards the sun's most northerly rising, either now or at some earlier date. The sun will not rise in prolongation of that line until A.D. 3260; it is only then that the process of precession will have carried the rising point so far. The Heel Stone does not, therefore, help to fix the date. It is of interest only to the spectators at the summer solstice,

who are ready to believe anything. Accordingly Lockyer found himself compelled to take his sight not from the Heel Stone or from the end of the ceremonial avenue, but from the ancient fortifications of Silbury towards which the ceremonial avenue points. He thus obtained an azimuth for the road of 49° 34′ 18″, whereas the present azimuth of the most northerly rising of the sun is 50° 25′ 30″. Assuming that the sun's rising at the summer solstice was the relevant point, and taking into account the change in the azimuths caused through precession he calculated that the structure had been erected in 1680 B.C. Fresh observations were taken by Stone, who obtained an azimuth of 49° 37′ 55″, which gave him 1400 B.C. as the date of construction. He was thus getting nearer the present day. On the other hand archaeologists who have studied the excavations have concluded that the erection took place in the early Stone Age. There thus exists a great gap between the archaeologists and scholars like Lockyer and Stone. From Stonehenge the ceremonial avenue leads down to the racecourse. Schuchhardt may be right when he claims that Stonehenge was not a temple but an elaborate tomb, the ceremonial avenue being arranged so as to make the ascent from the low to the high ground as easy as possible. The north-easterly direction of the road was thus a simple coincidence. The case is the same with the alignments of stones found in Brittany. Schuchhardt writes of them:

'The general picture conveyed is that of a grandiose arrangement for the worship of the dead. Alongside the tombs—impressive megalithic structures—a place of meeting is situated, capable of holding some thousands of people. It is approached by a wide stone-lined avenue, evidently starting from the main road. It is as though this avenue tried to catch visitors as they pass along the road and to lead them to the meeting place. In Egypt similar roads lead from the Nile to the pyramids which are situated off the river.'

In view of these facts it is hard to suppress a smile when watching the endeavours of scholars to fix exactly the direction of build-

ings or alignments of stones all over the world and to use them as the basis for adventures in prehistoric astronomy. The process started in England where Sir Norman Lockyer tried to prove that Stonehenge was a temple of the sun. He also carried out measurements outside England. His work was much helped by Nissen's book, *Orientation*. On the strength of numerous observations Nissen succeeded in suggesting that in some few cases the rising of the sun was taken into consideration when determining the lay-out of churches, though even then there were inaccuracies of up to 2°. Pagan temples he studied showed even greater errors, although Nissen used as his basis not the cardinal points, but the direction of certain bright stars at their rising, employing the difference in the azimuth to work out the date of construction. Lockyer in his day had made similar measurements with pagan temples and had been led to some rather improbable conclusions about the date of construction. To avoid these difficulties Nissen occasionally found himself compelled to use not the main axis of the temple, but the perpendicular axis; or else he assumed that the temple had originally been dedicated to some other deity whose star did rise in the direction to which the axis pointed. Or, again, he assumed that the axis pointed towards the setting of a certain bright star, though this ran counter to every astrological idea. In the end he simply assumed that 'stellar orientation in Rome, as in Greece, was a mystery'. The theory of orientation none the less gained fresh adherents. Its popularity was enhanced by Charlier's discovery that the cathedral at Lund points towards the sunrise on St. Laurence's day, to whom the cathedral was dedicated. In fact, however, the azimuth of the axis of the cathedral is not 114·3°, as Charlier said, but 109°, as Erlandsson found from new measurements.

Before 1910 Nissen and the two astronomers Lockyer and Charlier were the great authorities for anyone who made orientation his hobby. Stone circles of the kind found on prehistoric tumuli were at that period interpreted as being proto-Germanic observatories: astronomers were requested to draw lines connecting the centres of the circles and hence to deduce what particular

stars used to be observed by the alleged primitive astronomers. Teudt went a step further; he declared that the medieval structure on the Externstein was a temple of the sun and moon, and thought that the stone walls around the farm at Gierke had been constructed in conformity with the direction in which certain bright stars rose or set. But this was not all. Teudt maintained that these pagans had arranged their temples in such a way as to form straight lines running directly east and west or north and south. Röhrig thought that he had proved the existence of these so-called sacred lines in East Frisia. All over Germany ex-officers dug out their maps to look for similar lines, and were annoyed if they were contradicted. After all, it was an amusing pastime to try drawing such lines between the old towns on the map; where the distances were great the game was extended by looking for intermediate points like belvederes, cemeteries, slaughter-houses or foresters' huts. Nobody bothered to prove that these places existed a couple of thousand years ago, as should have been done. Later, when the Nazi Reich began and it was regarded as meritorious to prove the existence of pagan observatories, the scholars submitted themselves and gave their approval to Teudt's vapourings. Books like that by Friedrich appeared, proving that caves had been orientated, and nearly every paper carried reports about newly-discovered 'early German observatories' which resolved themselves into nonsense as soon as the report was locally checked. To carry this lunacy to a climax the Party would send for the dossiers of people who declined to conform; the only thing to stop the persecution was to refuse to play ball. After the fall of Hitler it became clear that everything had been imagined—the sacred lines, the astronomical walls, and the lofty state of astronomy among the pagan Germans. It was the morning after the night before, and it was now plain that all the labour put into calculating the risings of the stars had been a waste of time. People began to realise that, given the existence of thousands of stone circles, alignments, churches and stone walls, it would always be possible to find some pointing more or less exactly towards the rising or setting of the

sun or of the brighter stars, which can then be used to fix the age of the structure if we go back to 15,000 B.C. But all this is a matter for art-historians or archaeologists, and not for astronomers, who are rarely in a position to check the facts.

Another aberration is that concerning the calculation of the dates of the Ice Ages. In various geological formations traces of earlier epochs can be found going back to the earliest strata. Nothing certain is known about the time and nature of their origin. Now in 1920 and the following years Milankovitch published the result of his calculations, based upon the heat reaching the earth from the sun. His labours cover a period up to 600,000 B.C. The work proved immensely popular, more particularly since his earth-irradiation graphs could be used to explain the Ice Ages of the Diluvium. In Bavaria it could be shown that the Ice Ages advanced during four distinct periods between which warmer periods existed. This roughly corresponded with the graph for the irradiation of the earth if the periodical changes in the movement of the earth and in its position relatively to the sun are taken into consideration. Hence the deduction was hazarded that the Diluvial Ice Ages filled most of the period until 600,000 B.C. The enthusiasts disregarded the fact that the Bavarian Ice Ages did not occur elsewhere at the same time, and that it ought to have been possible to show the effects of the changes in the irradiation of the earth during the pre-Diluvial period, which however was impossible. In fact the Ice Ages going back to the very early strata cannot be explained as being the product of periodical changes in the movement of the earth; they were the results of changes in the atmosphere enveloping the earth or in the sun itself.

Incidentally nobody took notice of the fact that the irradiation which the earth was supposed to have received in the last 600,000 years was worked out on the supposition that the earth had followed a certain path which in turn was worked out from observations made between 1750 and 1850. Experience shows that a hundred years is far too short a period to permit precise statements relating to a period of 600,000 years.

• XII •

RIDDLES OF CREATION

IT is not only in estimating the dates of the Ice Ages that men have gone far beyond the limits previously imposed on them by their awareness of human fallibility. In dealing with the ages of some of the stars as well, astronomers eventually began to work in terms of milliards rather than of millions of years. The only open question remained whether their age was to be assumed to be more or less than ten milliards of years. The larger figure seemed more convenient because, as certain theorists believed, it left room for a bigger number of facts to be fitted in. Eventually, however, the smaller figure came to be favoured. One argument was that there are a number of stars (chiefly the blue ones) which cannot be more than ten to twenty million years old. A more important argument lay in the fact that the moment when the spiral nebulae began to rush apart, like fragments of an exploding shell, is supposed to have occurred about two milliards of years ago. This was the point of time when the stars probably took shape. And what of the sun, our nearest neighbour among the stars? For the sun, too, it appears to be true that it is not more than two milliard years old. It is not regarded as an eternal source of light and heat. It arose at a certain time, and it will perish at a certain time.

We come to the earth. Is it still regarded as an offspring of the sun, as a fragment torn from it which has gradually cooled? If so, it must be younger than the sun, and less than two milliards of years must have passed since its hard crust was formed. This view, however, conflicts with the conclusions reached by physicists who have examined the radio-active materials existing on the earth and have studied their rate of disintegration. Holmes, taking

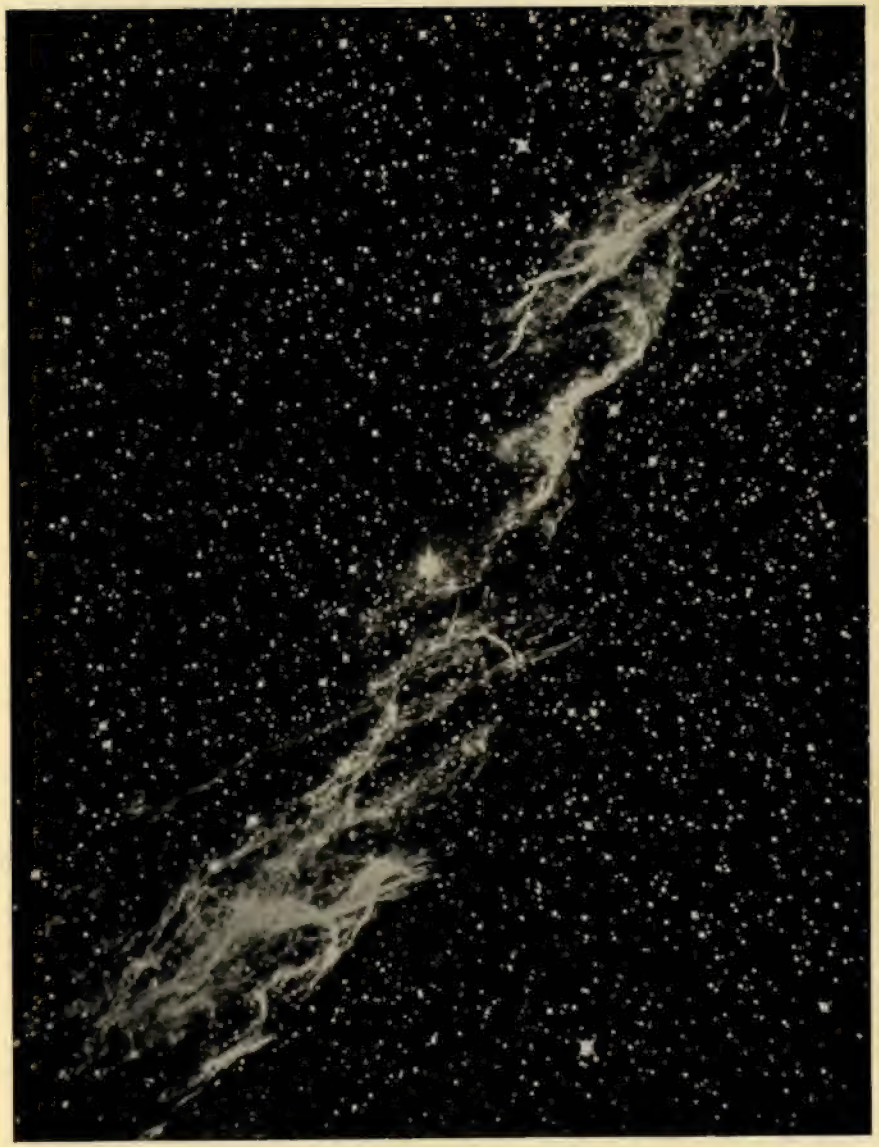
all available data into consideration, thinks that the earth is 3·35 milliards of years old. It would seem to follow that the earth had a firm crust before the sun and stars existed. As it is written in the Bible: 'In the beginning God created the heaven and the earth. And the earth was without form and void. . . . And there was light. . . . And God made two great lights; the greater light to rule the day, and the lesser light to rule the night: and He made stars also.' . . . A strange coincidence.

Another idea which is not infrequently found is that the sun was created a number of times. In Mexico the Aztecs held that there had been four ages, or suns, before the present sun. In their view, after the original Creation, the four ages or suns (Plate I) were created one after the other; then came the Flood and the heavens fell, in the spring at the time of the sowing festival. After this the heavens were re-erected above the earth, and men were created. They wandered in darkness without sun or moon; and fire was created for their benefit. It was only after this that the sun and moon came into being. A huge sacrificial stone, with the four proto-suns carved on it, was completed in A.D. 1479. Montezuma II caused it to be placed in 1512 on the top of the pyramid built in honour of the sun at Tenochtitlan.

We saw above that the Indians held similar views about the world ages and the world day, which they supposed to end with a general conflagration and a Flood. By a remarkable coincidence the idea of successive creations has latterly been gaining popularity.

XIV. *Prince Naram-Sîn under the protection of the stars, Babylonian* stele, ca 2700 B.C.

The Egyptian Goldsmith Saēse presenting the rising sun with a stele *in which a song in praise of the sun appears,* ca 1450 B.C.



xv. *Nebula (NGC. 6995) in the Swan. Taken with the 152 cm. mirror of the Mount Wilson Observatory*

• XIII •

DO THE STARS RESEMBLE LIVING BEINGS?

PLATO and Socrates thought that the stars had a divine nature. According to Plato a divine soul is immanent in the stars and moves them as the human soul moves the body. Aristotle attributed a divine force and a fifth element to them, the latter having no sort of kinship with the four terrestrial elements. The Stoics, observing the regularity and uniformity with which the stars moved in their courses, deduced that they possessed sensation, reason and volition. Later Greek philosophers assumed that a force they called sympathy was at work in the skies, effecting a parallelism between the events in the sky and those on earth. The world was for them a unified body within which the constituent parts were in a harmonious relationship. Christian teaching treated the stars as God's creatures and instruments, as can be seen in St. Francis's song of the sun. God manifests his omnipotence in the earth and in the luminaries in heaven. His creatures, particularly the stars in their courses, are perfect. Copernicus held similar ideas. He wrote that in the general view the state of immovability was more noble and divine than that of change. And again: 'I firmly hold that gravity is nothing else than a tendency implanted by the Creator's divine providence, by which every part of the world is enabled to strive after unity and wholeness which they achieve by coalescing in the form of a sphere.' Similarly Kepler saw in the world a testimony to the wisdom and greatness of the Creator, and in the mysterious movements of the planets he saw a manifestation of the Creator's wisdom. Kepler the astronomer was also in a measure Kepler the servant of God. Similar feelings animated Greek astronomers like Eratosthenes, Hipparchus and Ptolemy, who dedicated their

works and instruments to the Gods, and placed them within the temples. In this spirit Ptolemy's own epitaph must be appreciated:

'I know I am mortal, a creature of the day;
Yet in spirit I accompany the wandering stars as they circle round the Pole,
Though my foot no longer touches the earth. By the side of Zeus himself
I share the meal which preserves the Gods themselves in immortality.'

As early as the eighteenth century the larger telescopes showed numbers of bodies, not accounted for by earlier theories, in the skies. At that time eagerness for fresh discoveries was widespread; others had eyes only for the incomplete and unexpected, and shared Lichtenberg's view: 'Why should not there be stages of spirits reaching up to God; why should not our universe be a mere experiment, the work of prentice hands? I am speaking of our solar system, or of that great nebula which ends with the Milky Way. It may be that the nebulae observed by Herschel are merely specimen work or incomplete pieces of a task.' Words like these reflect the ambivalent feelings with which men were wont to look at the stars. Disappointment, too, is reflected in Schiller's verses:

'Do not talk so much of nebulae and suns.
Is Nature great only because she provides you with objects to enumerate?
True, your study is the most lofty in space
But, my friends, loftiness itself does not dwell in space.'

Gauss himself, the greatest astronomer and mathematician of the nineteenth century, felt oppressed by the mass of new discoveries in the skies. It was this feeling that prompted him in 1854 to write to his friend Alexander von Humboldt: 'Nature has more

at her disposal than mere man can suspect,' and, shortly before his death, he told a friend:

'There are questions which I would far rather see answered than the mathematical problems—questions of ethics, of our relation to God, of our final destiny and future. But their solution lies far beyond our powers, and beyond the field of scientific knowledge. . . . I do not care whether Saturn has five or seven moons; there are greater questions than this. Whether our soul lives for eighty years or eighty million years is indifferent. If it is destined to die some day, even eighty million years are all too short. We are thus compelled to accept the view which is supported by so many arguments of a non-scientific nature: that a spiritual order of the world exists side by side with the material one, and possessing as great a variety as that in which we live. This is the world which we seek to possess.'

When Gauss died in 1855 the planetary theory held the field. It had been successful to such a degree that almost every physical process was being explained in terms of movement. Eventually it was found that in certain cases this was impossible. In this way Planck's Quantum Theory arose, while a little later Einstein's Theory of Relativity was evolved to complement Newton's Theory of Motion. Both these modern theories imply a belief in an eternal order which is supposed to prevail in nature; they are characteristic for modern theoretical physics, which since then has so strikingly expanded its field to embrace every natural process. Its methods are employed to explain physical processes reaching into the very depth of space.

The ancient idea that the earth breathes has recently been resuscitated. The tides are no longer mentioned; other phenomena now provide a basis for the theory. In 1927 E. W. Brown observed irregularities in the movement of the moon, and deduced that the earth went through a process of regular breathing which caused the position of the observer to change in accordance with the

alternating contraction and expansion of the earth. In 1930 the geologist Haarmann thought that the earth's crust had a periodical movement. In 1927 J. Bartels showed that vibrations occur in the air enveloping the earth, vibrations which are strikingly regular and hardly influenced by rain and storm.

Side by side with these theories others have been evolved to explain the structure of the universe and what goes on in it. Kant, followed by Laplace, thought that the solar system had arisen out of a mass of gas, and this assumption was later applied to other bodies. Modern thought tends towards scepticism about providing a single explanation for the universe. The modern theory of evolution assumes that different branches of evolution occurred simultaneously, and similarly it is believed that a number of different ways of evolution exist for the stars. Recent observations have discovered three different types among the newly-born stars; again, some stars have been found to be short-lived, others long-lived. In each case the characteristic point is that different sorts of development have been found to exist for different sorts of stars. The system of development worked out quite recently by Lockyer has now been abandoned. It is now assumed that the course of development followed by the stars is irreversible. Here a point of similarity exists with living creatures; the same is true of the motion of the stars and of their multiplication through disintegration, as happens with comets or when a single star becomes a double one—phenomena studied by Poincaré in his day.

In the formation of animal species mutation plays a part, i.e. their development takes place by sudden bounds. A similar phenomenon can be observed in the stars. And as a regular order is restored after a mutation has taken place in an animal species, so a similar process can be assumed to exist among the stars. The solar system may have arisen in this way, and the order now prevailing in it may have developed later. This theory, however, does not fit completely. We know that the radiation from the sun is in a state of permanent but irregular (though only slightly irregular) change. The formation of the sun spots (important for the effect

they have on the earth) is more striking. The sun spots have been observed thousands of times in the last 340 years, and great trouble has been taken in trying to work out their exact periodicity, but in vain: it varies irregularly between 7 and 17 years. The sun governs the planets in accordance with Newton's Law of Attraction, which also governs the relationships among the planets. But does this law explain everything? Not so far as the planets which are close to the sun are concerned. Irregularities exist, most of which are explained by Einstein's Theory of Relativity. Striking irregularities have also been found to exist for Pluto, which is the most distant planet. In the intermediate space also—between Mars and Jupiter—a region exists conflicting with the idea that an eternal order prevails in the solar system. In this region thousands of minor planets, with a diameter of 3 to 300 miles, are in motion—obviously the product of one or more exploded planets. Some of the comets which enter this region also disintegrate gradually, causing falls of meteorites when these fragments enter the air around the earth and become incandescent. We thus see that there are phenomena in the solar system contradicting the theory that perfect order prevails in the skies. The variations from the rule are, however, slight in this particular field.

The time is ripe for new ideas. Hence it is not surprising that the theory of a continuous act of creation should be entertained.

XIV

MAN AND THE MYSTERIES OF THE STARS

THE dance of the stars is stilled, the music of the spheres is mute. There remains a mathematical figure. This is the view that some will hold about the solar system as set out by Copernicus, and they will go on to lament the disturbance caused by him when he uprooted the earth from its central position and made it rotate around the sun. These critics are hardly to be blamed when we consider how rapidly recent theories have lost favour and remember that the theories of Aristotle and of Ptolemy lasted a thousand years. Today change is rapid indeed. Fifty years ago Darwinism was a sufficient explanation of the development of species; today it has been almost completely abandoned. Forty years ago Einstein published his generalised Theory of Relativity, which had a revolutionary effect on astronomy. It foretold three phenomena—the red shift of the spectral lines of the sun, the deflection of the light ray during the near approach to the sun and the slow rotation of the major axes of the planetary paths. Enormous efforts were made to provide an astronomical proof for the correctness of the theory. On this point E. Findlay Freundlich wrote in 1952:

'These experiments have not yet been completed. Accordingly it is natural that physicists, anxious to know whether they can safely build upon the new foundations, tend to rest satisfied with an approximate experimental confirmation and consider it expedient to treat the experimental confirmation of the generalised theory as requiring no further development. Yet we cannot sufficiently stress the point that the real position is much less favourable. The new effects postulated by the Theory of Relativity undoubtedly exist; but it is far from certain that these effects have the values assumed by the theory; and that of course is what matters.'[1]

The number of observations increased enormously and with them the tendency to frame the results in the form of a simplified theory. New observations provide fresh starting points for the theorist, and often we find confirmed what Pringsheim said in 1910 in his *Solar Physics*:

'All in all we discover here what we have already encountered in the course of our observations, namely that a number of theories exist, all of them equally capable of explaining the observed phenomena. This is found everywhere in science. The only lasting things are carefully observed empirical data; as for theories, they arise and perish like leaves of grass or the generations of men.'

In later days the present century may well be named the revolutionary one. It looks as though our minds were to be moulded anew. Familiar views and theories are overthrown one after the other. A profound change is also beginning to take place in our view of the stars. The process began half a century ago. Until then it was held that the multiplicity of astronomical phenomena could be classified under a small number of heads and could be explained in terms of what is known about the solar system. It was everywhere assumed that the bodies observed were revolving about each other. This idea was applied in the most difficult cases. Gradually, however, it was realised that many processes are irregular and cannot be explained by saying that a given body is moving in a given path. The number of changing stars is growing steadily—stars which occasionally brighten without any fixed rule. Stars have been discovered which take no more than a

[1] From *Cosmology*, University of Chicago Press.

minute to gain brightness, and only a little longer to lose it again. Other and rare phenomena were noted where a feeble star for a few hours shines as bright as a nebula. Nature has so many surprises that the observer sometimes fails to understand the importance of an event and realises what was actually happening only when it is too late. The employment of photographic plates does not solve every riddle, particularly when the phenomenon occurs so quickly that the normal exposure (thirty minutes plus) provides no more than a feeble record of the sudden flaring of a star.

There is so much to observe in the heavens. There are the comets, whose tails seem to portend disaster, while their disintegration gives rise to questionings. There are the eclipses, which produce continually growing evidence about the form and structure of the sun, and its environment. There are the novae and the flare stars—phenomena which cause panics, arouse questions, and provide work for the pamphleteers. Again and yet again, people learn that nature can do more than man suspected.

This steady process of observation and explanation, this waiting upon celestial influences, this struggle against weariness and indifference—all these exercise a moulding influence on men, causing them to regard with anger or indifference the astrologers whose minds continue to move in outmoded ways of thought.

In the course of the last century millions of observations have been made and numbers of photographs taken. Telescopes have been constructed allowing the remotest objects to be fixed on a photographic plate, ready for study at any time. To what use have all these discoveries been put? For one thing, the existence of objects and phenomena has been demonstrated, which even the most deeply probing of Greek thinkers did not dream of: exploding stars, giant stars, dwarf stars, vast numbers of spiral nebulae, and their dispersal into the void; the connection between the sun, and events on earth; the exact aspects of the major planets. Yet the relevant question is this: what has the human reaction been to this flood of knowledge? Are astronomers no more than calculating machines, working out the planets' courses, and providing

material for the astrologers? Are they mere observers, compiling an ever-growing mass of observations? What ideas are awakened in them as they observe the structures in the sky? What are their ambitions? The devotees of mathematics are supplied with a never-ending field of mathematical interrelationships. The physicist is even more amply supplied. The skies provide an unearthly laboratory. Here are bodies from the finest cosmic dust to the heavy dwarf stars and those other gigantic stars far greater than the sun. Here are unlimited potentialities for study. Is it surprising that physicists and astronomers turn eagerly to these problems? The astronomer's first question will be whether the rule of law so clearly shown in the solar system extends to the stars. A hundred years ago it was firmly held that almost every natural process could be explained by natural laws and represented through a formula. Gradually this view had to be abandoned.

Is it possible to obtain a correct view of the universe? Let us look at the evening sky. We see the moon, we see Jupiter in the West and low on the horizon we see Venus; beyond them the host of the stars. Of the moon, Jupiter and Venus we can safely affirm that they are as they appear to be; light takes only a short time to reach us from them. With the stars it is different. The brilliant light which comes to us from Sirius started on its way nine years ago; the while light from Vega twenty-seven years ago. Much can have happened between then and now in these stars and in others. Some may have grown brighter in the interval (as did the middle star of Cassiopeia some years ago), and may have grown dimmer again. Clearly the aspect of the heavens as we see it at this moment does not correctly reflect the present arrangement of the stars in them; it merely affords a look into the past, a look which goes back further in proportion to the distance of the stars concerned. Let us take a small spiral nebula, which is so far away that its light takes 500 million years to reach us: what myriad events have taken place in the interval! New stars have begun to shine, multiplying their brightness a thousand-fold within a few days—the physi-

cists speak of gigantic chain reactions—and again quickly losing their light. More rarely, other stars, the so-called supernovae, have appeared. These are a thousand times more bright than the ordinary new stars; they rapidly diminish in brightness and turn into nebulae, temporarily or permanently. Entire groups of stars begin to shine with an incandescent surface, and are again extinguished. They have a life of no more than ten to twenty million years. Frequently a so-called pulsation of the stars is observed, i.e. a waxing and waning of their light having a certain periodicity. Many of these phenomena taking place in the spiral nebulae have long ceased to be by the time that light, that slothful messenger, brings us news of them.

If we want to imagine the cosmic processes we must take a special yardstick of time. A human life is far too short. Let us imagine a creature for which a thousand human years are equal to a day, and let its eyes, undazzled by the sun, reach as far as our biggest telescopes. What does such a creature observe in the course of one of its days? The stars are not fixed, but move along the skies, some quickly, others more slowly. Their surface glitters, for many are in a state of pulsation, with variable brightness. Some stars vanish because the period of their brightness has expired. Almost every minute a *nova* appears, and every half-hour some region is brightened through the explosion of a supernova. Man asks what all this means. Is the universe of stars full of mysteries? Are those astronomers right who stick to the regular events alone and refuse to concern themselves with the mysterious remainder?

When the astronomer, his work at the telescope completed, leaves the observatory at night, he takes pleasure in the silence around him. The noise of day has ceased. Scanty lights outline the streets, and above them stretches the leaden sky, sparsely illuminated by the yellowish crescent of the moon and the multiplicity of stars. Remote and unapproachable—how lovely are the skies! Let man rush and fly as far as he will, he will never reach the heavens. As he contemplates them he gathers fresh ideas on the infinity and creative power of God, ideas which have remained

fresh since the time of the Ancients. But when the astronomer returns to examine the stars he can no longer say, as Kant did: 'We cannot contemplate the universe without discovering the most perfect order in it, the most certain indications of the workmanship of God in the perfection of its inter-relations.' Nor can he agree with the French astronomer Laplace, who declared around 1789 that a superhuman intelligence using Newton's Law of Motion could calculate the past and present of the universe in every detail, as Newton did for the planets. The phenomena in the skies cannot but cause perplexity; they stand in the way of a belief that a simple explanation exists. Clearly what we know of the solar system cannot be directly applied to the rest of the universe.

All our ideas about the universe have undergone a profound change. At one time the stars were looked upon as symbols of immutability and men admired the perfect order in the skies. It seems that this order among the stars resembles that within crystals. The rule is rarely fulfilled, and the exception is the rule.

Birth and death seem to dominate the world; the earth alone enjoys an undisturbed regularity within the solar system. Is the earth destined to be a quiet observatory whence men may contemplate the universe? Or has nature a different intention? Let us consider the amazing manner in which man has conquered the earth, the vast increase in population which enforces a new exploitation of the soil. Let us note man's domination of the natural forces, unprecedented in any other living creature, and the acquisition of vast power through splitting the atom. And let us consider that man was driven to all this as though by a natural force, and that it was the contemplation of the skies that compelled him to ponder until the laws of nature became apparent. Can we doubt that this is a process which, steadily growing in strength, will some day penetrate the universe?

BIBLIOGRAPHY

Allen, Don C. The Star-crossed Renaissance; the Quarrel about Astrology and its Influence in England. Durham 1941.

Balss, H. Antike Astronomie. Munich 1949.

Beja, António de. Contra os Juizos dos Astrológos. Coimbra 1943.

Bidez, J. Julian der Abtrünnige. Munich 1940.

Biot, J. B. Études sur l'astronomie indienne et sur l'astronomie chinoise. Paris 1862.

al-Biruni. The Book of Instruction in the Elements of Astrology. Edited by Jarlāl Homa'i. Teheran 1940.

Bissing, Fr. W. v. Das Re-Heiligtum des Königs Ne-woser-re. Vol. I. Der Bau von L. Bochardt. Berlin 1905.

Bok, Bart. J. The Time-scale of the Universe (Monthly Notices of the Royal Astronomical Society, 106. London 1946, pp. 61–75).

Boll, Fr. Sphaera. Neue griechische Texte und Untersuchungen zur Geschichte der Sternbilder. Leipzig 1903.

— Sternglaube und Sterndeutung. Leipzig 1918.

— Die Sonne im Glauben und in der Weltanschauung der Alten Völker. Stuttgart 1922.

— Sternglaube und Sterndeutung. Die Geschichte und das Wesen der Astrologie. Leipzig-Berlin 1926.

Borchardt, L. Längen und Richtungen der vier Grundkanten der Grossen Pyramide bei Gise. Berlin 1926.

Bouché-Leclercq, A. L'Astrologie Grecque. Paris 1899.

Bredon, Juliet, and Mitrophanow, Igor. Das Mondjahr, Chinesische Sitten, Bräuche und Feste. Vienna 1937.

Brockelmann, C. Der Islam von seinen Anfängen bis zur Gegenwart (Weltgeschichte), Berlin 1910.

Brown, E. W. The Evidence of Changes in the Rate of Rotation of the Earth and their Geophysical Consequences, with a Summary and Discussion of the Deviations of the Moon and Sun from their Gravitational Orbits (Transactions of the Astronomical Observatory of Yale University 3, part 6, 1926, pp. 209–35).

Catalogus Codicum Astrologorum Graecorum. Vol. I to XII. Brussels 1898–1940.

Chatley, Herbert. The Egyptian Celestial Diagram (The Observatory 63, 1940, pp. 68–72).

Chu Coching. The Origin of Twenty-eight Mansions in Astronomy (Popular Astronomy 55, 1947; pp. 62–78).

Cramer, Fred. Astrology in Roman Law and Politics (Mem. Amer. Philos. Soc. Vol. 37, 1954).

Danzel, Th. W. Mexico I (Kulturen der Erde, Vol. XI). Hagen 1922.

Danzel, Hedwig and Th.-Wilh. Sagen und Legenden der Südsee-Insulaner, Hagen and Darmstadt 1923.

Danzel, Th. W. Magie und Geheimwissenschaft. Stuttgart 1924.

Das, Sukumar Ranjan. The Naksatras or the Constellation in Jaina Astronomy (JHA Commemoration Volume, Essays on Oriental Subjects, pp. 129–138. Poona 1937).

Drecker, Dr. J. Zeitmessung und Sterndeutung. Berlin 1925.

Dreyer, J. L. E. Tycho Brahe, Karlsruhe 1894.

Drower, Ethel. The Book of the Zodiac D.C. 31 (Oriental Translation Fund 36). London 1949.

Düwell, Fritz, and Diederich, Franz. Kometen. Wissenschaft und Aberglaube. Dresden 1910.

Eisler, Robert. Weltmantel und Himmelszeit. Munich 1910.

— The Royal Art of Astrology. London 1946.

Erlandsson, Hans. The Orientation of the Cathedral of Lund. Lund 1948.

Erman, Ad., and Ranke, H. Ägypten und ägyptisches Leben im Altertum. Tübingen 1923.

Faraut, F. G. Astronomie Cambodgienne. Saigon 1910.

Festugière, A. M. J. La révélation d'Hermes Trismegiste. Paris 1944–9.

Fischer, Otto. Wanderfahrten eines Kunstfreundes in China und Japan. Berlin 1939.

Frank, Erich. Plato und die Pythagoräer. Halle 1923.

Friedrich, Joh. Astrologie und Reformation. Munich 1864.

Friedrichs, Gustav. Germanische Astronomie und Astrologie während der Stein- und Bronzezeit. Die Gertruden-Höhle bei Osnabrück, eine germanische Kultstätte um 1600 v. Chr. Lindenberg.

Frobenius, Leo. Die Kultur Afrikas. Zurich 1933.

Gamow, G. Geburt und Tod der Sonne. Basle 1947.

Gandz, Solomon. Origin of the Planetary Week or the Planetary Week in Hebrew Literature (Proc. Americ. Acad. for Jewish Research 18, 1949, pp. 213–54).

Gerhardt, Os. Der Stern des Messias, Das Geburts- und das Todesjahr Jesu Christi nach astronomischer Berechnung. Leipzig 1922.

Getty, R. J. The Astrology of P. Nigidius Figulus (The Classical Quarterly 35, 1941, pp. 17–22).

Goldbeck, Ernst. Der Mensch und sein Weltbild. Leipzig 1925.

Gregory, Joshua. Astrology and Astronomy in the Seventeenth Century (Nature 159, 1947, pp. 393–4).
Greiner, Karl. Der astronomische Figurenfries am Hirsauer Klosterturm. Calw, 1934.
Grimme, Hubert. Das israelitische Pfingstfest und der Plejadenkult. Studien z. Geschichte u. Kultur d. Altertums. Paderborn 1907.
Groot, J. J. M. de. Universismus. Die Grundlage der Religion und Ethik, des Staatswesens und der Wissenschaften Chinas. Berlin 1918.
Guerin, J. M. F. Astronomie indienne. Paris 1847.
Gundel, W. Sterne und Sternbilder im Glauben des Altertums und der Neuzeit. Bonn and Leipzig 1922.
— Neue astrologische Texte des Hermes Trismegistos (Abh. d. Bayer., Akad. d. Wiss., Philos-histor. Abt. N.F., Part 12). Munich 1936.
— Dekane und Dekansternbilder. Glückstadt and Hamburg 1936.
Haarmann, Erich. Die Oszillationsthorie, eine Erklärung der Krustenbewegungen von Erde und Mond. Stuttgart 1930.
Haliburton, R. G. The Festival of the Dead. The Year of the Pleiades. 1863. (Reprint. Journal Canadian R. Astronom. Society 14, 1920, pp. 19, 59, 99, 144.)
Hammett, Fred. S. The Ancient Hindu Cosmogony as a Source of Sensory Classification antedating the Modern (Scientia 33, 1939).
Haskins, Ch. Homer. Studies in the History of Mediaeval Science. Cambridge 1927.
Hawley, W. Report on the Excavations at Stonehenge (The Antiquaries Journal, Vol. I–X). Oxford 1921–30.
Heath, Thomas L. Greek Astronomy. London 1932.
Hellmann, G. Doris. The Comet of 1577. New York 1944.
— Additional Tracts on the Comet of 1577 (Isis 39, pp. 172–4).
Hennig, Richard. Das Geburts- und Todesjahr Christi. Essen 1936.
Henseling, Rob. Das All und wir. Das Weltgefühl der Gegenwart und seine Urgeschichte. Berlin 1936.
Hermann, Alfred, and Schwan, Wolf. Ägyptische Kleinkunst. Berlin 1940.
Heseltine, G. C. The Kalendar and Compost of Shepherds. London 1930.
Hogrebe, Jos. Himmelskunde bei den Germanen. Frankfurt 1936.
Holmes, A. The Age of the Earth. (Annual Report of the . . . Smithsonian Institution. 1948, pp. 227–39).
Jeremias, Alf. Handbuch d. altorientalischen Geisteskultur. Leipzig 1913.
Johnson, Francis R. Astronomical thought in Renaissance England. Baltimore 1937.
Jordan, Pascual. Das Bild der modernen Physik. Hamburg 1947.

Kant, I. Allgemeine Naturgeschichte und Theorie des Himmels. 8. Hauptstück. Königsberg 1755.
King, W. J. H. Pioneer Desert Exploration (Geographical Journal 1931, pp. 541–7).
Kirfel, W. Die Kosmographie der Inder. Bonn and Leipzig 1920.
Kiss, E. Das Sonnentor von Tihuanaku u. Hörbigers Welteislehre. Leipzig 1937.
Klippel, Ernst. Unter Senusy-Brüdern, Drusen und Teufelsanbetern. Brunswick 1942.
Klöchler, Frh. v. Astrologie als Erfahrungswissenschaft. Leipzig 1927.
Kötz, Alfred. Über die astronomischen Kenntnisse der Naturvölker Australiens und der Südsee. Leipzig 1911.
Krause, Arthur. Die Astrologie. Entwicklung, Aufbau und Kritik. Leipzig 1927.
Kroll, Jos. Die Lehren des Hermes Trismegistos. Münster 1928.
Kubin, A. Die Planeten. Leipzig 1943.
Kubler, George, and Gibson, Ch. The Tovar Calendar (Mem. of the Connecticut Acad. XI, 1951). New Haven.
Laplace, P. S. Théorie analytique des probabilités. 3rd Edition-Oeuvres VII, Paris 1886, pp. VI–VII.
Leistner, L. W. The Western Church and Astrology during the Early Middle Ages (Harvard Theol. Rev. 34, 1941, pp. 251–75).
Lewis, George Cornewall. An Historical Survey of the Astronomy of the Ancients. London 1862.
Lockyer, Norman. The Dawn of Astronomy. London 1894.
— Stonehenge and other British Stone Monuments. London 1909.
Lübke, A. Der Himmel der Chinesen.
Lundmark, Knut. On Greek Cosmogony and Astronomy. Lund 1937.
— Nya Himlar. Stockholm 1943.
Mädler, J. H. Geschichte der Himmelskunde. Brunswick 1873.
Makemson, M. Wor. The Morning Star rises. New Haven 1941.
McCombe, Leonard. Bei den Navaho-Indianern (Atlantis 1949, p. 7).
Menon, C. P. S. Early Astronomy and Cosmology. London 1932.
Müller, Rolf. Himmelskundliche Ortung auf nordisch-germanischem Boden. Leipzig 1936.
Nielsen, Detlef. Die altarabische Mondreligion und die mosaische Überlieferung. Strasbourg 1904.
Nilsson, Martin P. N. The Rise of Astrology in the Hellenistic Age. Lund 1943.
— Astrology in antiquity (Lychnos 1943, pp. 21–32).
Nissen, Heinrich. Orientation. Studien zur Geschichte der Religion. Berlin 1906–10.

Normann, Friedr. Mythen der Sterne. Stuttgart 1925.
Noti, Severin. Land und Volk des Königlichen Astronomen Dschai-singh II, Maharadscha von Dschaipur. Berlin 1911.
Ohlmarks, Ake. Quelques aspects de l'identification de constellations sur les rochers sculptés par rapport à l'histoire des religions. Lund 1937.
Oppenheim, S. Das astronomische Weltbild im Wandel der Zeit. Leipzig 1912.
Palacios, Enr. The Stone of the Sun and the First Chapter of the History of Mexico (The University of Chicago, Department of Anthropology, Bull. VI). 1921.
Pfeifer, Erwin. Studien zum antiken Sternglauben. Leipzig 1916.
Pringsheim, E. Physik der Sonne. Leipzig 1910.
Reiners, Ludwig. Steht es in den Sternen? Eine wissenschaftliche Untersuchung über Wahrheit und Irrtum der Astrologie. Munich 1951.
Reinhardt, Karl. Poseidonius. Munich 1921.
— Kosmos und Sympathie. Munich 1926.
Reinsberg-Düringsfeld, Otto Frh. v. Das festliche Jahr in Sitten, Gebräuchen, Aberglauben und Festen der germanischen Völker. Leipzig 1898.
Reuter, O. S. Germanische Himmelskunde. Munich 1934.
Robinson, J. H. The Great Comet of 1680. A Study in the History of Rationalism. Northfield 1916.
Röhrig, Herb. Heilige Linien durch Ostfriesland. Aurich 1930.
Roscher, W. H. Über Selene u. Verwandtes. Leipzig 1890.
Rufus, W. C. Korean Astronomy. Seoul 1936.
Samaha, Abdel Hamid. Notes as to Cosmological Ideas in al Quran. Lund 1938.
Sarton, G. Introduction to the History of Science. Vol. I–III. 1927–48.
Saussure, L. de. Origine babylonienne de l'astronomie chinoise. Paris 1923.
— Les origines de l'Astronomie Chinoise. Paris 1930.
Schiaparelli, Giov. Die Astronomie im Alten Testament. Giessen 1904.
Schnabel, Paul. Berossos und die babylonisch-hellenistische Literatur. Leipzig 1923.
Schoeps, H. J. Umstrittene Grenzgebiete. Astrologie—Trugschluss oder Wissenschaft? Erlangen 1950.
Schuchhardt, C. Alteuropa. Berlin 1926.
Schultz, Wolfgang. Zeitrechnung und Weltordnung. Leipzig 1924.
Schwarzbach, Martin. Das Klima der Vorzeit. Stuttgart 1950.
Sigerist, H. E. The Sphere of Life and Death in Early Mediaeval Manuscripts (Bull. of the History of Medicine 11, 1942, pp. 292–303).
Somerville, Boyle. Astronomical Indications in the Megalithic Monument at Callanish (Journal Brit. Astronom. Association XXIII, pp. 83–96).

Spinden, Herbert J. Sun Worship (Annual Report of the . . . Smithsonian Institution 1939, Washington 1940, pp. 447–69).
Stange, Alfred. Das frühchristliche Kirchengebäude als Bild des Himmels. Cologne 1950.
Stegemann, Viktor. Astrologie und Universalgeschichte. Leipzig 1930.
Stevens, Frank, and *Sumner.* Stonehenge. London 1929.
Stirling, M. W. Concepts of the Sun among American Indians (Annual Report of . . . Smithsonian Institution 1945, Washington 1946, pp. 378–400).
Stone, E. H. Stonehenge. London 1924.
Strauss, H. A. Der astrologische Gedanke in der deutschen Vergangenheit. Munich 1926.
Struve, Otto. Stellar evolution. Princeton 1950.
— Continuous Creation (Astronomical Society of the Pacific, Leaflet 270). 1951.
Stubel, A., and *Uhle, M.* Die Ruinenstätten von Tiahuanaco. Breslau 1892.
Svenonius, Bj. On the Orientation of the Egyptian Pyramids. Lund 1936.
Tallmadge, G. Kasten. On the Influence of the Stars on Human Birth (Bull. of the History of Medicine 13, 1943, pp. 251–67).
Teudt, W. Germanische Heiligtümer. Jena 1929.
Thiele, Georg. Antike Himmelsbilder. Berlin 1898.
Thompson, R. C. The Reports of the Magicians and Astrologers of Nineveh and Babylon. London 1900.
Thorndike, Lynn. Science and Thought in the Fifteenth Century. New York 1929.
— A History of Magic and Experimental Science. Vol. I–VI. New York 1929–1941.
— A Hitherto Unnoticed Criticism of Astrology. Liber de reprobatione iudiciorum astrologiae (Isis 31, 1939, pp. 68–78).
— The Latin Translations of the Astrological Tracts of Abraham Avenezra (Isis 35, 1944, pp. 293–302).
— Dates in Intellectual History (Journal of the History of Ideas, Suppl. I). New York 1945.
— Peter de Limoges on the comet of 1299 (Isis 36, 1945).
— More Light on Cecco d'Ascoli (The Romanic Review 1946, pp. 293–306).
Ullstein. Weltgeschichte, Orient. Berlin 1910.
Vanki. Histoire de l'Astrologie. Paris 1906.
De la Ville de Mirmont. L'Astrologie chez les Gallo-Romains. Paris 1904.
Voigt, H. Die Geschichte Jesu und die Astrologie. Leipzig 1911.
Weber, Har. Das chinesische Horoskop. Leipzig 1930.

Wedel, Th. Otto. The Mediaeval Attitude Towards Astrology, Particularly in England (Yale Studies in English LX). New Haven 1920.
Wegner, Max. Altertumskunde. Freiburg and Munich 1951.
Weinstein, M. B. Der Untergang der Welt und der Erde in Sage und Wissenschaft. Leipzig 1914.
Weizäcker, C. Fr. v. Die Geschichte der Natur. Stuttgart 1949.
Wickersheimer, Ernest. Recueil des plus Célèbres Astrologues et quelques hommes doctes faict par Symon de Phares. Paris 1929.
Wilhelm, Richard. Geschichte der chinesischen Kultur. Munich 1928.
Wolf, Werner. Der Mond im deutschen Volksglauben. Bühl 1929.
Woolley, C. L. Ur und die Sintflut. Leipzig 1930.
Zinner, E. Die Reizempfindungskurve (Zeitschr. für Sinnenphysiologie 61, 1930, pp. 247–66).
— Geschichte der Sternkunde. Berlin 1931.
— Die frühgermanische Sternkunde (26. Bericht. d. Naturforsch. Gesellschaft Bamberg 1932, pp. 3–26).
— Die Orientierungstheorie (26. Bericht. 1932, pp. 26–46).
— Die astrologische Treffsicherheit (Gesundheitslehre 35, 1932, pp. 170–173).
— Der Mensch und die Sterne (Fortschritte d. Medizin 51, Berlin 1933).
— Die Helligkeitsänderungen der Sterne der Hauptreihe des Russell-Diagrammes (Astronom. Nachrichten 249, Kiel 1933, pp. 69–92: Über die Eiszeiten, pp. 86–92).
— Johannes Kepler. Lübeck 1934.
— Mittelalterliche Sonnengucker (Das Weltall 34, Berlin 1935, pp. 76–8).
— Das Sonnenloch im Dom (Bamberger Blätter 13, 1936, pp. 49–52).
— Leben und Wirken des Johannes Müller von Königsberg, genannt Regiomontanus. Munich 1938.
— Die Sterne des Hipparch (Veröffent. IV. d. Remeis-Sternwarte zu Bamberg, 1939, p. 83).
— Der Sternenmantel Kaiser Heinrichs. Himmelskunde und Rechenkunst im alten Bamberg. Bamberg 1939.
— Die Horoskope der Weltentstehung (Forschungen und Fortschritte 19, 1943, pp. 99–101).
— Entstehung und Ausbreitung der coppernicanischen Lehre. Erlangen 1943.
— Die griechischen Himmelsbeschreibungen (31. Bericht. d. Naturforsch. Gesellsch. Bamberg, 1948, pp. 1–23).
— Schickalsscheiben, Tolederbriefe und Horoskope (31. Bericht der Naturforsch. Gesellschaft Bamberg, 1948, pp. 24–40).
— Neue Angaben über das Verhalten der Tiere bei Sonnenfinsternissen (32. Bericht d. Naturforsch. Gesellsch. Bamberg, 1950, p. 49).

— Astronomie, Geschichte ihrer Probleme. Freiburg and Munich 1951.
— Die astronomischen Vorlagen des Sternenmantels Kaiser Heinrichs (33. Bericht. d. Naturforsch. Gesellsch. Bamberg 1952, p. 41).
— Die astronomische Bestimmung der Empfängniszeit und der Schwangerschaftsdauer (Sudhoff's Archiv 37, 1953, pp. 432–7).
— Das Verhalten der Tiere während der Sonnenfinsternis am 30. Juni 1954 (34. Bericht d. Naturforschenden Gesellschaft Bamberg, 1954, pp. 13–16).
— Zur Deutung der astrologischen Bleikapsel in Freiburg (Forschungen und Fortschritte, Berlin 1956).
Zwack, George M. The Return of Halley's Comet and Popular Apprehensions. Manila 1910.

INDEX

GEORGE ALLEN & UNWIN LTD
London: 40 Museum Street, W.C.1

Auckland: 24 Wyndham Street
Bombay: 15 Graham Road, Ballard Estate, Bombay 1
Calcutta: 17 Chittaranjan Avenue, Calcutta 13
Cape Town: 109 Long Street
Karachi: 254 Ingle Road
New Delhi: 13–14 Ajmere Gate Extension, New Delhi 1
São Paulo: Avenida 9 de Julho 1138–Ap. 51
Sydney, N.S.W.: Bradbury House, 55 York Street
Toronto: 91 Wellington Street West

FROM EARTHQUAKE, FIRE AND FLOOD

RONALD HEWITT, M.SC., F.R.G.S.

A sudden catastrophe in the shape of a hurricane, earthquake or flood and a whole community faces disaster and widespread ruin. This absorbing book studies the forces behind the tremendous upheavals of these natural phenomena. The whole world is the field of study and the author ranges from local tragedy, like the Lynmouth disaster, to the great catastrophes, like the eruption of Krakatoa or the San Francisco earthquake. Most of the events described have been chosen in order to illustrate important scientific data, which has led to at least a partial understanding of the physical phenomena.

Much of the interest and value of the book lies in the scientific treatment of the physical agents of disaster, but Mr. Hewitt has not failed to depict vividly the human story. The general and human description of such portentious events as the Mont Pelée eruption, the East Coast floods, the destruction of Pompeii and the great American hurricanes will have the greatest appeal to the general reader.

From Earthquake, Fire and Flood is then a book for the inquisitive mind—for those interested in natural phenomena and in the relation of man to his environment. Both layman and the student will find it stimulating and absorbing. *Illustrated. Demy 8vo. About 16s net*

THE FRAME OF ORDER

JAMES WINNY, M.A.

The imagery of Elizabethan plays and poems is so inextricably mingled with the scientific and philosophical ideas of the time that this selection of long extracts has outstanding value. The extracts have been chosen from scientific and philosophical treatises published in the lifetime of Shakespeare and present the thought and outlook of the period in some of its important and characteristic aspects. Most of the passages come from works not reprinted since their original appearance, though a long extract from Bright's *Treatise of Melancholy* has been included. The subject matter of the eleven extracts, ranged under the heads of Man, Society, and the Universe, encompasses such diverse topics as the complexions, the nature of the soul, political theory, the Copernican system, meteors, and planetary influences.

The editor, who has been teaching English at Cambridge since 1949, has made use of his experience to choose passages of philosophical writing most relevant and helpful to the study of Elizabethan literature. Indeed, the philosophical beliefs of the period are the natural complement of contemporary poetry and drama. In a lucid preface he relates the various extracts and provides an authoritative explanatory background. The book should be of most use and interest to those who are already broadly acquainted with the forms of Elizabethan belief, and who wish to extend their knowledge beyond the popular summaries by contact with the works in which sixteenth century outlook was outlined and defined. *Demy 8vo. About 28s net*

By P. E. Cleator

THE PAST IN PIECES

It was Heinrich Schliemann's excavations at the mound of Hissarlik, and his discovery of the site of the supposedly fabulous city of Troy, which served to arouse an active and intelligent interest in the past, as opposed to idle curiosity and mere speculation. Today, so great is the amount of material evidence which has been brought to light—in Mesopotamia and in Crete, in Mexico and in the Nile Valley, in Ceylon and in Peru—that the making of a detailed study of it has necessarily become the task of the specialist, his labours confined to this or that aspect of some particular age or culture.

Prefaced by an account of how finds are made and examined, interpreted and preserved, *The Past in Pieces*, deals in turn with each of the three main geographical-chronological divisions of the historic period—the Oriental (Asian and Egyptian affairs, from the beginning of written records to Roman times); the Mediterranean (the era of Greco-Roman influence which ended with the death of Constantine the Great); and the pre-Columbian American (Mayan, Incan, and other such epochs)—thus affording a highly informative glimpse behind the archaeological scenes, and incidentally providing a fascinating story of hidden treasures and long-lost cities, of royal burial chambers and ruined temples, of mysterious monuments and now-vanished peoples.

Illustrated. Demy 8vo. 21s net

INTO SPACE

'It would be difficult to name an author more competent to write on this subject and it is possible to say, right away, that this book gives the clearest details of space flight requirements, and the progress we have made towards space flight, that has yet appeared.... It is most readable and will be gobbled up by every young, or old, person capable of the slightest enthusiasm about man's ultimate conquest—Space. A book to be purchased at all costs.'—*World Science Review.*

'A fine study, historical and speculative, of space travel.... He emerges as one of the world's highest authorities on astronomical matters.'—*Evening News.*

'A convincing argument for the possibility of travel to at least the nearer planets.'—*Birmingham Post.*

Second Impression. Illustrated. Demy 8vo. 16s net

THE BEQUEST OF THE GREEKS

TOBIAS DANTZIG

In mathematics all roads lead to Hellas and any attempts to study the historical development of modern mathematics must make a thorough examination of the Greek contribution. This volume deals therefore with the ideas and issues which agitated the Greeks from Thales to Pappus and which have survived and are still alive today. Professor Dantzig envisages two later volumes: *Centuries of Surge* will describe the rebirth of mathematics and its prodigious progress in the seventeenth and eighteenth centuries, and *The Age of Discretion* will cover developments in the nineteenth century.

Professor Dantzig's brilliantly organised work grew out of his experience with *Number: the Language of Science.* This earlier book gained immediate recognition as an exceptionally clear account of a vital mathematical problem and has been revised and enlarged three times. His new historical survey exhibits the same stimulating qualities of lucidity and thoroughness.

Illustrated. Demy 8vo. 18s net

MATHEMATICS IN WESTERN CULTURE

MORRIS KLINE

This refreshing treatment of mathematics as a branch of our culture answers the question: What contributions has mathematics made to Western life and thought apart from techniques that serve the engineer? By presenting a remarkably fine account of the influence mathematics has exerted on the development of philosophy, the physical and social sciences, religion, literature, and the arts, the book amply supports the contention that mathematics is a major constituent of our culture.

Among the topics treated are the evidence supplied by mathematics for the Greek (and modern) doctrine that natural phenomena are designed and orderly; the importance of mathematics in the creation and defence of the heliocentric theory of planetary motion; the application of mathematics by the Renaissance painters to the development of perspective; the guidance that mathematical method afforded Descartes in his search for truth; the inspiration derived from the universal mathematical laws of the Newtonian age for the Age of Reason and the subsequent reorganization of philosophy, literature, and religious, ethical, political, and economic thought; the importance of the statistical approach to knowledge and the resulting clash between the statistical and deterministic views of nature; the influence of non-Euclidean geometry on man's belief in truth; and the theory of relativity.

Professor Kline feels that mathematicians have failed to transmit the larger significance of the great mathematical creations. His own book is a highly successful attempt to bridge the gap between the specialized subject matter of mathematics and the broad patterns of our culture.

Illustrated. Med. 8vo. 30s net

SCIENCE FOR THE CITIZEN

LANCELOT HOGBEN

In *Mathematics for the Million* Professor Hogben expounded the language of science in the light of social progress from prehistory to modern times. In this new work he has done the same thing for science itself. Here the entire realm of science is his field—astronomy, physics, chemistry, biology, psychology—described and interpreted as a tool which shapes society and which society in turn sharpens to a keener edge. Distinguished alike by its clarity of exposition, its breadth of learning, and its humanistic outlook, this book is a magnificent achievement, a veritable encyclopedia of man's knowledge of himself and the universe he lives in.

But this is far more than a book to which one can go for 'information'. It is aimed at certain definite audiences and has a definite purpose. It is partly written, says the author, 'for the large and growing number of intelligent adults who realize that the *Impact of Science on Society* is now the focus of genuinely constructive social effort. It is also written for the large and growing number of adolescents who realize that they will be the first victims of the new destructive powers of science misapplied'. Then, by calling his book 'a primer for the age of plenty', Professor Hogben states its purpose: to show us the instruments that are at hand for the creation of a just and rational social order—a civilization in which there is no hunger, no homelessness, no wars, no racial hatreds, and as little disease and insanity as possible, and where the fruits of the earth may be leisurely enjoyed in beautiful surroundings by healthy, decent men and women. The instruments are at hand, Professor Hogben proves, for the inventory of scientific achievement is great and its powers vast.

Thus this book is not only an essential education for the alert citizen—essential because scientific discoveries affect the everyday lives of everyone—but also an adventure into the genius of the past and the potential achievements of the future. Here the reader will learn what the electrical engineer, the physical chemist, the biologist, and the physiologist can already do and what they will soon be able to do for the founding of a new social culture. He will learn, in brief, that scientific humanism is justified in asserting that the duty of a Government is not merely to create work, but to create leisure and abundance. Who can doubt that the reading of such a book will make us better citizens? *Ninth Impression. Illustrated. Demy 8vo. 35s net*

GEORGE ALLEN & UNWIN LTD

The Stars Above Us

ERNST ZINNER

ALLEN AND UNWIN